PB81-189797

Standards Applicable to Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities Under RCRA (Resource Conservation and Recovery Act), Subtitle C, Section 3004 Ground-water Monitoring (40 CFR 265, Subpart F)

(U.S.) Environmental Protection Agency
Washington, DC

May 80

U.S. Department of Commerce
National Technical Information Service
NTIS.

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO.	2.	3. Recipient's Accession No. PB81 189797
4. Title and Subtitle Standards Applicable to Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities Under RCRA, Subtitle C, Section 3004 Ground-water Monitoring			5. Report Date May 1980 6.
7. Author(s)			8. Performing Organization Rept. No. 1941.9
9. Performing Organization Name and Address U.S. Environmental Protection Agency 401 M Street, S.W. Washington, D.C. 20460 Office of Solid Waste			10. Project/Task/Work Unit No. 11. Contract(C) or Grant(G) No. (C) (G)
12. Sponsoring Organization Name and Address Same.			13. Type of Report & Period Covered 14.

15. Supplementary Notes

16. Abstract (Limit: 200 words) This document is one of a series providing support for regulations issued by the U.S. Environmental Protection Agency (EPA) under Subtitle C of the Resource Conservation and Recovery Act (RCRA). The regulations represent the initial effort for nationwide control of hazardous waste from point of generation, through transportation, treatment, and storage, to point of ultimate disposal.

This document covers standards applicable to hazardous waste management facilities, specifically to monitoring groundwater at facilities with "Interim Status"--that is, they were in existence on November 19, 1980 (the effective date of the regulations) have notified EPA of their activities, and have applied for a permit, which has not yet been processed.

17. Document Analysis a. Descriptors

b. Identifiers/Open-Ended Terms
Resource Conservation Recovery Act regulations
Hazardous waste facility standards
Ground-water monitoring

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
	20. Security Class (This Page)	22. Price

(See ANSI-Z39.18) See Instructions on Reverse

OPTIONAL FORM 272 (4-77)
(Formerly NTIS-35)
Department of Commerce

PB81-189797

BACKGROUND DOCUMENT

STANDARDS APPLICABLE TO OWNERS AND OPERATORS OF HAZARDOUS WASTE TREATMENT, STORAGE, AND DISPOSAL FACILITIES UNDER RCRA, SUBTITLE C, SECTION 3004

Ground-water Monitoring
(40 CFR 265, Subpart F)

This document (ms. 1941.9) provides background information and support for EPA's hazardous waste regulations

PRODUCT OF:
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

U.S. ENVIRONMENTAL PROTECTION AGENCY
May 1980

TABLE OF CONTENTS

		Page
I.	INTRODUCTION	1
	A. Legislative Mandate	1
	B Key Definitions	2
II.	RATIONALE FOR REGULATION	3
	A. Importance of the Ground-Water Resources	3
	B. Damage Case Summaries	3
	C Federal and State Precedents	6
III.	SYNOPSIS OF PROPOSED REGULATION	9
IV.	COMMENT ANALYSIS AND RATIONALE FOR CHOSEN ACTION	12
	A. Comments on Definitions	13
	B. Specific Monitoring Requirements	22
	1. Leachate Monitoring System	23
	2. Applicability	31
	3. Ground-Water Monitoring System	49
	4. Sampling and Analysis	75
	5. Preparation, Evaluation and Response	98
	6. Statistical Methods (Appendix IV)	109
	7. Recordkeeping and Reporting	118
V.	REFERENCES	125
Attachment No. 1 - Damage Cases		131
Attachment No. 2 - State Laws and Regulations		133

(3)
4 blank

BACKGROUND DOCUMENT

GROUND-WATER MONITORING

I. INTRODUCTION

A. Legislative Mandate

Section 3004 of the Resource Conservation and Recovery Act of 1976 (RCRA) requires that the EPA Administrator promulgate regulations establishing such performance standards, applicable to owners and operators of facilities for the treatment, storage, or disposal of hazardous wastes, as may be necessary to protect human health and the environment. Section 3004(2) specifically requires that these standards include requirements respecting satisfactory monitoring at hazardous waste management facilities (HWMF).

The Agency interprets this provision to provide clear authority for the RCRA Subtitle C regulations to require various types of monitoring at HWMFs. This document deals with regulations for ground-water monitoring at hazardous waste management facilities.

The fundamental objective of ground-water monitoring at HWMF sites is to serve as a continuing assessment of the quality of the ground water in the uppermost aquifer which flows beneath the HWMF. Introduction and transport of contaminants in such an aquifer could, if undetected, result in a serious threat to human health and the environment. The HWMF should be monitored in such a manner as to detect, as early as possible, the movement of contaminants from the HWMF into the ground water to allow prompt implementation of measures

designed to correct any such contamination, if necessary. This concept is implicit in the regulations discussed herein.

B. Key Definitions

The following definitions concerning ground-water monitoring were the subject of substantial comment on the proposed rule and are discussed in depth in Section IV below:

"Annular Space"
"Aquifer" (and "Usable Quantity")
"Endangerment"
"Ground Water"
"Hydraulic Gradient"
"Leachate Monitoring System"
"Monitoring Well"
"Unsaturated Zone"
"Water Table"

Other key definitions used in this document are:

"Facility" means all land and appurtenances, on it and to it, used for the treatment, storage and/or disposal of hazardous waste. A facility may consist of several treatment, storage, and/or disposal operational units (e.g., one or more landfills, surface impoundments, land treatment areas, or combinations of them). (See Part 260, Subpart B.)

"Leachate" means the liquid, including any suspended components in the liquid, that has percolated through or drained from hazardous waste. (See Part 265, Subpart N.)

"Saturated zone" or "zone of saturation" means that part of the earth's crust in which all voids are filled with water. (No comments, proposed definition is retained.)

II. RATIONALE FOR REGULATION

A. Importance of the Ground-Water Resource[68]

Almost one-half of the population (48%) of the United States depends upon ground water as a source of drinking water. Of the total population, 29% use ground water delivered by community systems and another 19% have their own domestic wells (Figure 1). The rural population dependent upon ground water is much higher (95%) than the population served by public supplies (36%). The largest use of ground water is irrigation which accounts for 67% of total ground-water withdrawal. Public supplies are the second largest consumer of ground water. Figure 2 illustrates the breakdown of ground-water withdrawal by use.

B. Case Summaries

The potential for and existence of ground-water contamination from hazardous waste land disposal facilities is well documented in an EPA unpublished list of damage cases by Abby Howard.[22] Of the two hundred forty-six cases surveyed in this document one hundred twenty-six involved some form of ground-water contamination. The following damage cases illustrate a few examples of the potential for ground-water contamination.

(1) The Wisconsin Department of Natural Resources (DNR) reported the existence of localized heavy ground-water contamination in the vicinity of the Ansul Company, which manufactures agricultural herbicides in Marinette, Wisconsin.[76]

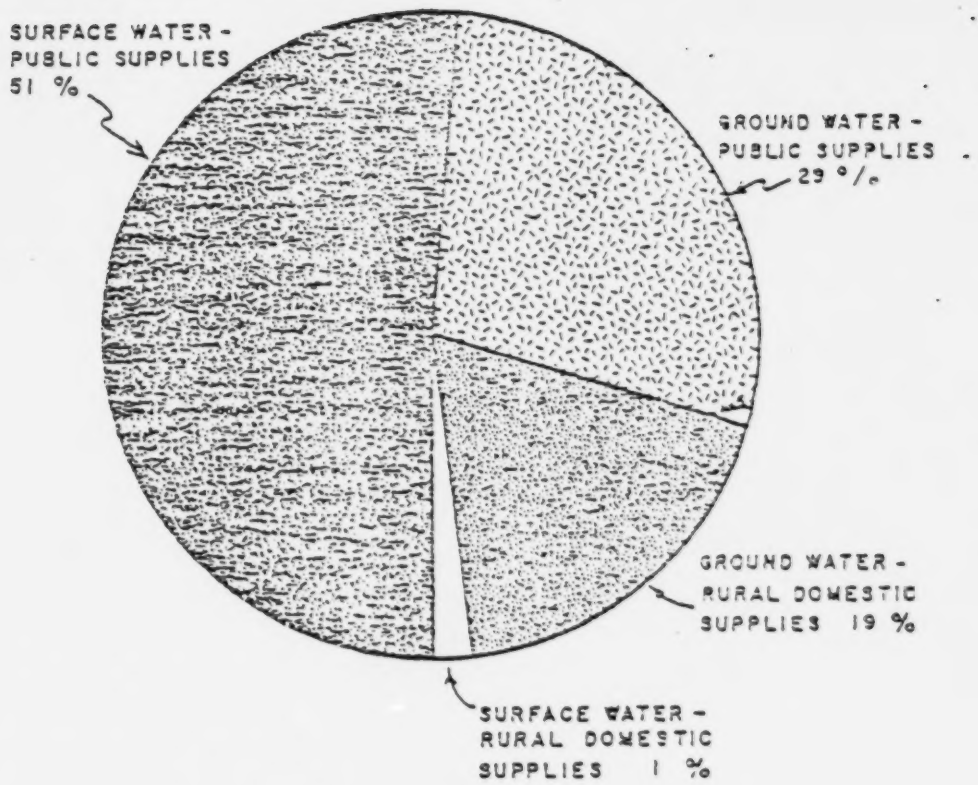

Figure 1. Population served by source and supply, 1970.[68]

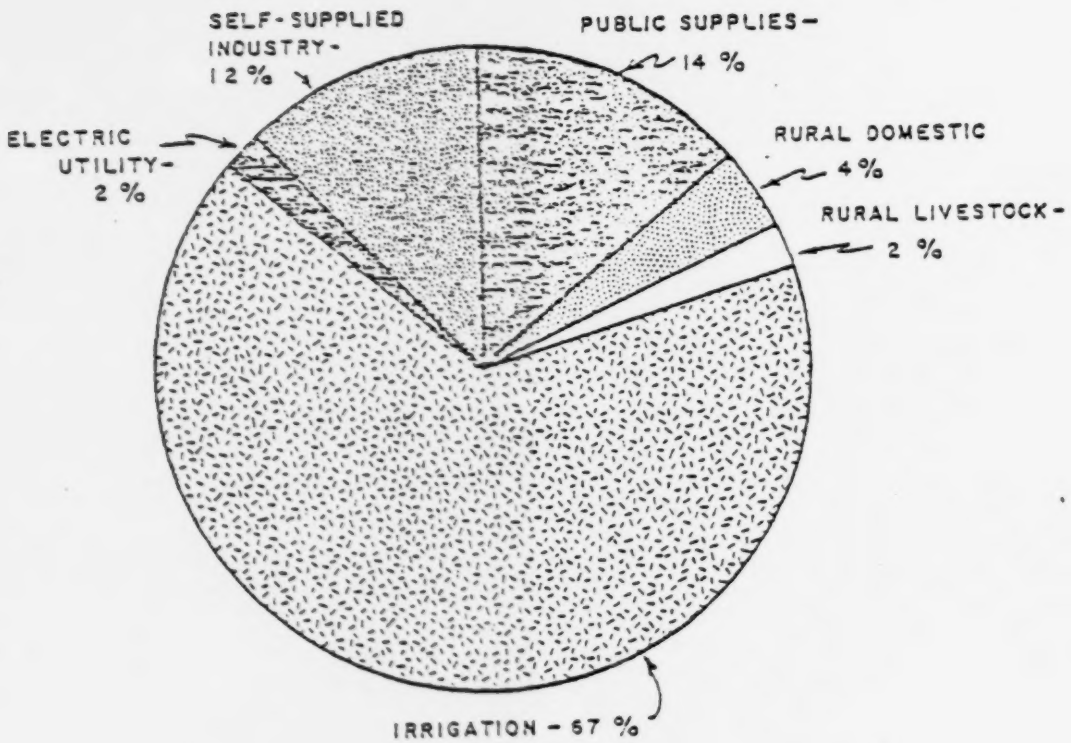

Figure 2. Total ground-water withdrawal, by use, 1970.[68]

(2) An aluminum plant in Monroe County, Ohio, had grossly contaminated the ground water under its site. The source of contamination was leachate from a used tailing pond and used potline piles.[44]

(3) A chemical plant in Hamilton County, Ohio, which utilizes two infiltration lagoons for waste disposal had contaminated a very productive aquifer in the area. Discovery of this occurred when new wells were installed on a nearby property.[43]

(4) In 1972 shallow wells were installed near an arsenic pesticide disposal site for the purpose of serving as a water supply for a local construction company. Thirteen employees were stricken with what was later diagnosed to be arsenic poisoning.

(5) Contamination of ground water has occurred in Myerstown, Pennsylvania, as a result of disposal of arsenic wastes from surface storage areas of a commercial laboratory.[47]

C. Federal and State Precedents

In developing these regulations, the Agency considered a number of existing federal and state regulations and standards.

The following is a summary of these precedents as they relate to ground-water monitoring:

1. EPA Recommendations for the Disposal of Pesticides and Pesticide Containers[(49)]--

These guidelines recommend that, if appropriate incineration facilities are not available, organic pesticides may be disposed by burial in a "specially designated landfill." Such landfills are those at which complete long term protection is provided for the quality of surface and subsurface waters from pesticides and which are equipped with monitoring wells, sampled and analyzed to detect any leakage.

2. EPA PCBs - Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions[(51)]--

These regulations require disposal of certain PCB wastes in chemical waste landfills which must be designed and operated to provide containment of PCB wastes. Such

landfills must be equipped with a ground-water monitoring system described in the regulations. The monitoring system installation, sampling and analysis requirements are very similar to those described in these hazardous waste management regulations.

3. EPA Land Disposal Facilities and Practices Criteria[14]--

While these regulations do not specifically require ground-water monitoring at disposal facilities, they do, however, require that complying facilities not discharge certain substances to ground water. Similar to these hazardous waste management regulations the ground water quality standards of the criteria are to be applied at the edge of the waste (i.e., the solid waste boundary).

4. Selected State Regulations and Standards --

A review of Agency files has yielded a list of 13 states which require some form and extent of ground-water monitoring at hazardous waste management facilities. These regulations and standards are summarized in Attachment No. 2.

In addition, a survey conducted by the Minnesota Pollution Control Agency has yielded information regarding the status of State regulatory requirements for ground-water monitoring at waste disposal facilities.[12]

In consideration of the Congressional mandate in RCRA, the importance of protecting ground-water resources and the potential for harm to these resources from hazardous waste management activities, as evidenced by the preceding damage case summaries, the Agency has determined that ground-water monitoring requirements need to be included in these final rules. The concern for minimizing the extent of ground-water contamination, caused by waste management activities, through reliance upon ground-water monitoring systems, as demonstrated in the summaries of state regulations, supports the Agency

decision to require ground-water monitoring in these rules. Examination of damage cases and Federal/State monitoring requirements has aided the Agency in better assessing the magnitude of ground-water contamination attributed to disposal activities as well as yielding valuable information on monitoring systems and technologies (e.g., well number and construction, etc.).

III. SYNOPSIS OF PROPOSED REGULATION

RCRA Section 3004 Regulations for ground-water monitoring at hazardous waste landfills and surface impoundments were proposed as §250.43-8 in the Federal Register [43 FR 59005] on December 18, 1978. Proposed §250.43-8 also dealt with leachate monitoring systems. These systems have been deleted from the final rules for reasons discussed in Section IV and will not be discussed here.

The proposed rule specified that a ground-water monitoring system must consist of at least four monitoring wells. One well was to be placed hydraulically upgradient from the facility to supply information on background quality of ground water. A minimum of three wells were to be placed downgradient within the facility property boundary at different depths to maximize the detection of any leachate which had migrated into ground water. At least one downgradient well was to be placed immediately adjacent to the active portion of the facility. All wells were to be cased and the annular space backfilled. A "Note" allowed variances to the number and depth of wells in certain cases.

All wells were to be sampled monthly for one year (beginning at least three months before receiving wastes at a new facility) to provide background statistics on ground water quality. These samples were to be subjected to a comprehensive analysis to quantify the concentrations of all parameters included in EPA's Interim Primary and

Proposed Secondary Drinking Water Standards, beryllium, nickel, cyanide and phenols, and to detect the presence of organic constituents by scanning by gas chromatography. In addition, these samples were to be analyzed for specific conductivity, pH, chloride, total dissolved solids, dissolved organic carbon, and the principal hazardous constituents of the hazardous waste handled at the facility. This latter analysis was called a "minimum analysis," and was a sub-set of the comprehensive analysis. A "Note" allowed variances to the list of these analyses in certain circumstances.

After the one-year period to establish background levels, samples were to be taken quarterly or semi-annually, depending upon the ground-water flow rate, and subjected to the minimum analysis. However, at least annually, the wells were to be sampled and subjected to the comprehensive analysis.

If the analyses of samples showed a significant difference in any parameter from the background levels (as determined by the Student's t, single-tailed test at the 95 percent confidence level), the facility owner/operator was to discontinue facility operations, notify EPA (within seven days), determine the cause of the discrepancy, and determine the extent of ground-water contamination.

Otherwise the facility owner/operator was to keep records of monitoring activities and analysis data for three years and send the analytical data to EPA on a quarterly basis.

During the interim status period, the proposed rules applied only to owners/operators of facilities where a ground-water monitoring system was already in place.

IV. COMMENT ANALYSIS AND RATIONALE FOR CHOSEN ACTION

A few commenters specifically addressed these requirements as they apply to facility owners and operators with interim status. These commenters suggested that the proposed rules apply to all facilities during the interim status period. Since these comments dealt with the scope of the proposed rules, rather than their substance, the comments are discussed in the background document on purpose, scope, and applicability. However, since the final interim status regulations now do indeed require ground-water monitoring at all facilities, not just those with a monitoring system already in place, all substantive comments on the proposed rules are discussed, below, except those relating specifically to permitted facilities. Comments related to permit award will be addressed in the background document for 40 CFR 264, Subpart F.

Similarly, comments which addressed the proposed ground water human health and environmental standard (GWHHES) are not addressed here. The GWHHES requirements were not proposed for facilities under interim status and have not been included in these final interim status regulations.

The remaining comments received can be grouped into those addressing (1) definitions concerning ground-water monitoring, and (2) specific proposed monitoring requirements. In the following analysis, the comments are addressed in that order.

A. Comments on Definitions

1. "Annular Space"

The term "annular space" was defined to mean the space between the bore hole and the casing. A bore hole is the man-made hole in a geological formation for installation of a monitoring well.

Rationale for Final Definition

No comments were received on the proposed definition of this term. The Agency feels that common English usage of this term is generally understood. Therefore, this term has not been defined in these final regulations. Use of the term in the regulations is clarified where necessary.

2. "Aquifer" (and "Usable Quantity")

The term "aquifer" was defined in the proposed regulations as a geologic formation that is capable of yielding usable quantities of ground water to wells or springs.

Rationale for Proposed Definition

This definition is essentially that found in the dictionary, for example: "aquifer - an underground layer of porous rock, sand, etc., containing water, into which wells can be sunk" (Webster's New World Dictionary, Second College Edition). In order to make this definition somewhat more specific the Agency added language limiting aquifers to those underground soils capable of yielding "usable quantities" of ground water and specifically requested (in the preamble to the proposed regulations) comments on this concept and suggestions on defining "usable quantities." The Agency also suggested that 600

gallons/day (an estimate of the needs of an urban family of 4 people) could serve as a lower limit.

Comments Received

Since the term "usable quantity" is the key to the definition of aquifer, virtually all comments on the definition related to this term. In general, comments on the suggestion of 600 gallons/day argued the impracticality of specifying such a number. It was stated by one commenter that some aquifers in California serve as drinking water supplies with yields only in the range of 50-200 gallons/day. Other commenters, in less specific terms, explained that the minimum acceptable yield of an aquifer for drinking water purposes depended upon available alternative sources of drinking water. If no suitable surface water supply or other ground-water source of drinking water is available, and drinking water is necessary, then an aquifer yielding any measurable quantity may be considered "usable." Another way in which this opinion was expressed was that "usable quantity" should be a case-by-case determination based upon local need and resources. It was also suggested that the definition have an accompanying "Note" explaining that "usable quantity" could only be determined on a local basis.

Another suggestion attempting to avoid the problem of specifying "usable quantity" would replace this term with for beneficial use for a long period of time."

Several comments discussed the issue of quantity vs. quality of ground water. From one extreme, a commenter suggested protection of all ground water regardless of current quality or potential yield in order to assure underground sources of water for future generations. Similarly, commenters suggested that any aquifer capable of yielding water, or at least those yielding water containing less than 10,000 mg/l total dissolved solids, be considered as "usable" in these regulations. From the opposite extreme, a commenter suggested that the regulations only address "potable subsurface water."

Comment Analysis/Rationale for Chosen Action

In general, the Agency agrees that it is infeasible to specify a minimum yield for "usable quantity," in the definition of "aquifer," which could be applicable throughout the country. The Agency desires, however, to protect even low yield ground-water aquifers, which supply drinking water, from contamination from hazardous waste management activities. Toward this end, the Agency has determined that the suggested minimum of 600 gallons/day was too high. As indicated, this consumption rate is the typical requirement for a single family dwelling for 4 people in an urban area. In such an area, this design consumption rate includes provision for such uses as fire protection in addition to gardening and other non-human consumption uses. In a rural area the actual water consumption rate for a family of 4 people could be dramatically less. An EPA Water Supply Bulletin suggests that 50 gallons/capita/day can satisfy most domestic water

requirements.[67] Even in light of this discussion the Agency also recognizes that 200 gallons/day (rural family of 4 people) may be too high or too low in specifying a minimum yield to define "usable quantity" in specific local situations. For these reasons the Agency has decided to modify the proposed definition for "aquifer" in the final regulations. No specification for "usable quantity" has been included. However, the Agency does wish to draw attention to the fact that the yield of an aquifer is an important factor in determining the degree of aquifer protection needed; therefore, it has used the term "significant amount" in the definition. Only prevailing local conditions determine whether an aquifer is capable of yielding "significant amounts" of water.

The definition of "aquifer" in the final regulation reads:

> "Aquifer" means a geologic formation, group of formations, or part of a formation capable of yielding a significant amount of ground water to wells or springs.

3. "Endangerment"

The term "endangerment" was defined to mean the introduction of a substance into ground-water so as to:

(i) Cause the maximum allowable contaminant levels established in the National Primary Drinking Water Standards in effect as of the date of promulgation of this Subpart to be exceeded in the ground-water; or

(ii) Require additional treatment of the ground water in order not to exceed the maximum contaminant levels established in any promulgated National Primary Drinking Water regulations at the point such water is used for human consumption; or

(iii) Reserved (Note: Upon promulgation of revisions to the Primary Drinking Water Standards and National Secondary Drinking Water Standards under the Safe Drinking Water Act

and/or standards for other specific pollutants as may be appropriate.)

Rationale for Proposed Definition

The basis of this definition is a concept included in the Safe Drinking Water Act which relates ground water protection to avoidance of increased treatment. Any addition of substances to ground water which would require additional treatment to render the water fit for human consumption constitutes endangerment.

Comments Received

Commenters stated that application of the primary drinking water standards, only, to ground water quality was unprotective and that broader standards should be specified. Others commented that changes in the primary standards may not always be incorporated in these RCRA rules. Other comments argued that the endangerment concept was inconsistent with objectives of RCRA Section 3004 which requires protection of human health and the environment, not only drinking water.

Response to Comments and Rationale for Final Definition

The term endangerment was used in the proposed regulations in the §250.42-1 Ground-water Human Health and Environmental Standard. This standard has been deleted from these final rules; therefore, the term endangerment has also been deleted.

4. "Ground Water"

The term "ground water" was defined to mean water in the saturated zone beneath the land surface.

Rationale for Proposed Definition

This definition was derived and modified from two references, the Webster's Collegiate Dictionary and the Glossary of Geology, published by the American Geological Institute. The objective of this definition was to emphasize that only the water beneath the land surface that is contained in the saturated zone is considered ground water.

Comments Received

The major comment received was that a clear distinction between the terms "aquifer" and "ground water" should be made such that the terms cannot be used interchangeably.

Response to Comments and Rationale for Final Definition

The term "ground water" is clearly defined to mean water in the saturated zone and the term "aquifer" means a geologic formation ... yielding ground water. In one case the water is defined and in the other the formation which is capable of yielding ground water is defined. The Agency does not use these terms interchangeably in the final rule.

Final Definition

The proposed definition is retained for final regulations.

5. "Hydraulic Gradient"

The term "hydraulic gradient" was defined to mean the change in hydraulic pressure per unit of distance in a given direction. The proposed definition was derived from the understanding that the pressure exerted by a column of water above a given datum changes as a function of the height of that column of water. In

an unconfined aquifer the hydraulic gradient is a change in water level (and thus a change in pressure exerted by that water) per unit distance.

Comments Received

Commenters stated that the use of the phrase "change in hydraulic pressure" is incorrect. They stated that a clearer, more widely applicable definition would be "a change in hydraulic head per unit of distance." Their rationale was that the slope of the water table in an unconfined aquifer defines the hydraulic gradient, yet there is no pressure change along the water table in either the up-or down-gradient direction. It does represent a change in total head due to change in water-table elevation.

Response to Comments and Rationale for Final Definition

The Agency agrees that the proposed wording of the definition is not the generally accepted or understood definition. However, since this term is no longer used in these final regulations, no definition for this term is included.

6. "Leachate Monitoring System"

The term "leachate monitoring system" was defined to mean a system beneath a facility used to monitor water quality in the unsaturated zone (zone of aeration) as necessary to detect leaks from landfills and surface impoundments. (For example, a pressure-vacuum lysimeter may be used to monitor water quality in the zone of aeration.)

Rationale for Proposed Definition

This definition was intended to convey the basic goal of a system that would detect leachate from a facility in the underlying unsaturated zone.

Comments Received

The major comment was that the definition precludes the use of leachate monitoring devices which do not rely on collection of samples for quantitative anlaysis.

Response to Comments and Rationale for Final Definition

The final regulations have deleted leachate monitoring as a requirement; therefore, a definition for this term has not been included in these regulations.

7. "Monitoring Well"

The term "monitoring well" was defined to mean a well used to obtain water samples for water quality analysis or to measure ground-water levels.

Comments Received:

No comments were received on this definition.

Rationale for Final Definition

The Agency has decided not to specify a formal definition for this term and instead to rely on normal English usage of the term.

8. "Unsaturated Zone"

The "unsaturated zone" ("zone of aeration") was defined to mean the zone between the land surface and the nearest saturated zone, in which the interstices are occupied partially by air.

Rationale and Support for Proposed Definition

The proposed definition was taken from U.S. Geological Survey Water-Supply Paper 1988, "Definitions of Selected Ground Water Terms,"[29] and modified considerably to accommodate the desired environmental protection conveyed in the proposed regulations. In

the proposed regulations leachate monitoring within the unsaturated zone was required. Because of this it was important that the unsaturated zone be clearly defined.

Comments Received

Comments on the proposed definition suggested that the definition should be changed to read "... the zone between the land surface and the nearest saturated zone," thus deleting the phrase "... in which the interstices are occupied partially by air." No rationale was submitted for this change.

Response to Comments and Rationale for Final Rule

The proposed definition attempted to describe the nature of the unsaturated zone by adding the phrase "in which the interstices are occupied by air." Reconsideration of the definition has revealed that this clarification, describing the nature of the unsaturated zone, is not necessary. A definition which merely describes the unsaturated zone as that zone between the land surface and the water table is adequate.

The definition in the final regulations reads:

"Unsaturated zone" or "zone of aeration" means the zone between the land surface and the water table.

9. "Water Table"

The term "water table" was defined to mean the upper surface of the zone of saturation in ground waters in which the hydrostatic pressure is equal to atmospheric pressure.

Rationale for Proposed Definition

The proposed definition was a modified dictionary definition. The modification incorporating the concept of "hydrostatic pressure" was intended to better convey the meaning of a water table with regard to the proposed regulations.

Comments Received

One comment stated that as defined, "water table" refers to the top of an aquifer. This is often the case but it does not hold true in the case of a confined aquifer. Another comment suggested that the definition be clarified with regard to hydraulic pressure, that is, explain that pressure increases downward from the water table.

Response to Comments and Rationale for Final Definition

The Agency agrees that the proposed definition was not as clear as it could have been. In the final regulations the term "water table" has been deleted from the final regulations including the definitions. Where necessary, the Agency is relying on normal English usage.

B. Specific Monitoring Requirements

Proposed §250.43-8 addressed both ground-water and leachate monitoring, and was organized as follows:

a. Ground-water monitoring system

b. Leachate monitoring system

c. Sampling and analysis

d. Recordkeeping and reporting.

As mentioned earlier, the Agency has deleted leachate monitoring at landfills and surface impoundments from the final rule. In this section, the comments received on this issue, and the Agency's rationale for deleting the provision, are presented first.

The final interim status rule for ground-water monitoring has been restructured as follows:

§265.90 Applicability

§265.91 Ground-water monitoring system

§265.92 Sampling and analysis

§265.93 Preparation, evaluation and response

§265.94 Recordkeeping and reporting.

The discussion of comments received on the proposed rule and the Agency's rationale for the final rule are discussed in that order.

1. Leachate Monitoring System

Synopsis of Proposed Regulation

The proposed regulations required that a leachate monitoring system be installed beneath a facility and above the ground water in the zone of aeration. Drilling through the bottom or sides of a facility to install the system was prohibited. The purpose of the monitoring system was to collect samples in the zone of aeration.

The "Note" in the proposed regulations waived this monitoring system requirement if the owner/operator could demonstrate that an

alternative leachate monitoring technique would detect leaks as effectively as the prescribed system. The "Note" identified as acceptable substitutes the Leachate Detection and Removal System described in §250.45-2(b)(13) for landfills and the Leachate Detection System described in §250.45-3(c)(3) for surface impoundments.

Sampling and analysis of the quality of water obtained from the leachate monitoring system was required monthly for twelve (12) months at existing facilities and at least three (3) months prior to operation of new facilities to establish the background quality of water in the zone of aeration. The proposed regulations specified both a comprehensive analysis list, to be used for establishing background quality and annually thereafter, and a minimum analysis list to be determined quarterly.

"Notes" included in the proposed regulations waived these requirements if it could be demonstrated that an adequate volume of water for analysis could not be obtained from the leachate monitoring system.

Rationale for the Proposed Regulation

While recognizing that leachate monitoring technology was still being refined, the Agency included these requirements for leachate monitoring, using available equipment, to provide an "early warning that ground-water contamination may occur." The Agency contended that a "leak must move through and cause extensive contamination of the zone of aeration before it reaches and contaminates the ground

water," and that, therefore, ground-water monitoring alone was insufficient to protect the environment.

Comments Received

Many comments were received on the leachate monitoring requirements included in the proposed regulations. Only a few of these comments supported the proposed requirements. These commenters suggested leachate monitoring as a necessary complement to ground-water monitoring. One commenter, however, suggested that ground-water monitoring only need be initiated if the leachate monitoring system indicated contamination in the zone of aeration. Other commenters suggested deletion of the "Note" allowing variances to the requirement.

The majority of comments received recommended deletion of the leachate monitoring requirements and reliance upon ground-water monitoring to detect contamination for a variety of reasons discussed below. A few commenters recommended that the leachate monitoring requirement could be waived by the Regional Administrator depending upon facility location and design. While no rationale was offered, some commenters suggested waiving these requirements except at surface impoundments or except at facilities using synthetic liners.

Waiving the leachate monitoring requirement at existing facilities was the most frequently suggested comment. Commenters suggested that leachate monitoring technology was poor, at best, and nearly impossible at existing facilities especially since drilling through

the bottom or sides of the facility liner was prohibited. Most commenters agreed that the liner should not be penetrated, although a few commenters stated that this was unnecessarily restrictive and that drilling through a liner could be accomplished without creating a pathway for contaminants to enter the ground water.

Three possible techniques for installing a leachate monitoring system at existing facilities were identified and critiqued by commenters. The first involved digging a trench around the facility to a depth greater than that of the waste and then drilling or jacking monitoring probes beneath the facility. Commenters stated that equipment for drilling and jacking is scarce and expensive. Furthermore such equipment is limited to about a 200 foot maximum penetration which means that no facility greater than 400 feet in diameter could be so equipped. One commenter included a cost analysis to retro-fit a 200 foot square surface impoundment, which showed that the cost of trenching and drilling would be about the same as the cost of facility replacement. Another installation technique identified was angle drilling for monitoring probe placement but was described as possible only at very small shallow facilities.

The final technique identified by commenters involved removal of the waste and installation of a leachate collection and removal system. Commenters explained that this technique would also equal or exceed the cost of facility replacement.

The availability of leachate monitoring technology and equipment was challenged by commenters. The only two monitoring techniques identified by commenters were lysimeters (pressure/vacuum) for sampling followed by analysis, and electrical conductivity measurements. Electrical techniques were alleged to be capable of detecting the presence of contaminated water but not quality. As with lysimeters, electrical techniques increase in effectiveness with increasing moisture. Regarding use of lysimeters, one commenter summarized the concerns raised by other commenters by describing the experience at a new New Jersey facility equipped with lysimeters in the aeration zone as follows:

- lysimeters were subject to blinding (plugging) and did not respond well to backflushing
- lysimeters were susceptible to damage, during and following installation
- there was no way to know whether lysimeters were working or not (i.e., no moisture present or plugged--result is the same)
- it was impossible to repair or replace defective lysimeters.

Other problems with lysimeters identified by commenters included:

- lysimeters are sampled through small diameter tubes extending from the lysimeter to the sampling point at the waste boundary which could result in insufficient sample volume due to loss of sample on the walls of the tube (one commenter suggested a 20 foot limit)
- lysimeters only sample the immediate surrounding soil volume necessitating a very large number of lysimeters for complete coverage beneath a large facility, with no guidance included in the proposed regulations

Commenters suggested that the only effective means of leachate monitoring would be the use of a double liner equipped with a collection and removal system between the liners. They further asserted, however, that this is not zone of aeration monitoring and that this is impractical for existing facilities since this cannot be accomplished without removal of all the waste.

Some commenters rejected the entire concept of leachate monitoring because:

- where natural in-place soils are used as a facility liner there may be no zone of aeration above the water table
- a saturated clay liner may be more effective in minimizing leachate migration than an unsaturated soil
- any samples obtained from a saturated liner may contain leachate contaminants but this would not necessarily indicate impending ground-water contamination
- even where a zone of aeration exists it may be very difficult to decide where to place a leachate monitoring system if seasonal fluctuations of the ground-water table are large
- detection of leachate in the zone of aeration may not significantly precede detection in the ground-water monitoring system.

Finally some commenters rejected the "Note" allowing reduced monitoring and analysis if an insufficient volume of sample were obtainable from the leachate monitoring system since a full leachate monitoring system would have to be installed to demonstrate that it was unnecessary.

Agency Response/Rationale for Chosen Action

As a result of these comments, the Agency undertook a reevaluation of available information on leachate monitoring technology.

Information available to EPA on the subject of aeration zone monitoring is very limited. Both the EPA ground-water monitoring manual[18] and recent Office of Research and Development studies[73] discuss various devices and techniques for obtaining water (leachate) samples from the aeration zone beneath waste disposal facilities. In all reported applications of aeration zone monitoring for the presence of leachate in soil pore water, the investigations have been research-oriented. In general, these investigations have attempted an assessment of the impact of leachate on water present in the aeration zone beneath landfills. EPA is unaware of any applications of aeration zone monitoring to determine the integrity of containment design waste disposal facilities.

Regarding reliance upon aeration zone monitoring for detection of the failure of containment design waste disposal facilities, EPA is forced to rely upon a common-sense evaluation of the available technology in the absence of research or "real world" experience.

The most commonly utilized aeration zone monitoring device has been the suction (i.e., pressure-vacuum) lysimeter.[18] These devices are porous, usually ceramic, cylinders emplaced in the soil. By alternating application of vacuum and pressure, soil pore water is drawn into the lysimeter from the soil immediately surrounding the lysimeter. The volume of soil contributing pore water is dependent upon the characteristics of the soil and the vacuum applied. In general, the contributing soil volume is small as is the lysimeter.[18]

In order, therefore, to sample (monitor) an entire horizon beneath a waste management facility, the spacing of emplaced lysimeters must be small. At large facilities, the number of needed lysimeters could be several hundred if all possible leaks are to be detected. Even if such large numbers of lysimeters were to be installed beneath a landfill or surface impoundment, the logistics of monitoring these devices would be onerous because of the large number of plastic tubes (two connected to each lysimeter) required for sampling. Other disadvantages of lysimeters include their reported tendency to deteriorate and/or plug over time.[73] Research applications of these devices have seldom exceeded two years. Once "fouled," these devices are irreplaceable beneath a landfill or surface impoundment.

Deletion of the leachate monitoring requirements for landfills and surface impoundments from the final regulations reflects the suggestions of commenters. EPA considers the ground-water monitoring provisions discussed below as the only suitable technique enabling detection of leachate contamination of ground water as the leachate migrates from the boundary of waste management.

In the case of land treatment facilities, however, the Agency has realized the feasibility and appropriateness of aeration zone monitoring. While aeration zone monitoring was not included in the proposed regulations, these final regulations include this requirement. Both soil core analyses and lysimeter sample analyses are requirements now contained in Subpart M of these regulations.

While the Agency is aware that some of the same problems with lysimeter monitoring beneath landfills and surface impoundments would be encountered beneath a land treatment facility, most of these problems could be dealt with.

Two major differences exist when comparing the feasibility of lysimeter monitoring beneath a land treatment facility versus a landfill or surface impoundment. At a land treatment facility there is continued access to emplaced lysimeters for repair or replacement, and moisture in the zone of aeration is expected, at least for a short period of time following waste application or rainfall. Such monitoring beneath a land treatment facility is not for the purpose of detecting discrete leaks, but rather is to measure the progress of applied waste through the soil. The monitoring objective is facility effectiveness; a spacing of installed monitoring devices which provides representative indications of the movement of waste constituents through the facility can readily be achieved at land treatment facilities.

A more complete discussion of zone of aeration monitoring at land treatment facilities is included in the background document for Subpart M.

2. Applicability

Synopsis of Proposed Regulation

The proposed regulations, §250.43-8, required the owner/operator of a landfill or surface impoundment to install, maintain, and operate a ground-water monitoring system (GWMS) and a leachate monitoring

system (LMS) and to comply with specified sampling and analysis and recordkeeping and reporting requirements.

The proposed regulations also included a "Note" in §250.43-8(a) with a provision to allow for no or a lesser degree of ground-water monitoring if the owner/operator demonstrated that the geologic and hydrologic conditions underlying the facility indicated no potential for discharge to ground water.

The requirements for interim status in the proposed regulations stated that both leachate and ground-water monitoring must be conducted where a facility has a ground water and/or leachate monitoring system in place. Therefore, only those provisions under sampling and analysis, and recordkeeping and reporting (250.43-8(c) and (d)) of the proposed regulations were required for facilities under interim status.

Rationale for the Proposed Regulation

The objective of the proposed leachate and ground-water monitoring requirements was to detect any discharge of contaminants from hazardous waste management facilities as early as possible. The LMS was intended to intercept leachate in the unsaturated zone. The GWMS was required so as to detect contaminant migration from the facility into ground water.

The proposed "Note" was intended to provide the owner/operator an opportunity to demonstrate that lesser or no ground-water

monitoring was appropriate at his facility based on geologic and hydrologic conditions.

Comments Received/Rationale for Chosen Action

Ground-water and leachate monitoring. One commenter felt that requiring the installation of both an LMS and a GWMS where "no problems have been detected" was too cautious and too expensive. The commenter recommended choosing one monitoring system or the other on a case-by-case basis depending on site geology, drainage, weather and related site-specific factors.

The Agency does not agree that the proposed requirement for an LMS and a GWMS at landfills and surface impoundments was either too cautious or too expensive. The initial objective of subsurface-facility monitoring was to detect ground-water contamination as early as possible. Therefore, an LMS was a proposed requirement for landfills and surface impoundments. The LMS requirement was deleted for landfills and surface impoundments for technical reasons only, as explained in the discussion on leachate monitoring. However, as fully described in that discussion, leachate monitoring is both technically feasible as well as useful at landfarms (now called land treatment facilities) and is required in the final regulations for those facilities.

The Agency believes that a GWMS alone is sufficient at landfills and surface impoundments to detect ground-water contamination, since

downgradient monitoring wells are required to be located and installed where they will be able to detect contaminant discharges as early as possible, as described in the discussion of well location.

In contrast with landfills and surface impoundments, no ground-water monitoring was proposed for land treatment facilities. However, comments on the desirability of ground-water monitoring at land treatment facilities were requested in the preamble of the proposed regulations for land treatment facilities, especially to seek reaction to requiring only soil monitoring as the measure of environmental performance. The Agency, in its rationale for proposing only soil monitoring at land treatment facilities, suggested that soil monitoring would detect waste constituents long before ground-water monitoring. The Agency was not, and still is not, aware of any documented case of ground-water contamination resulting from hazardous waste land treatment.

Commenters presented opinions both for and against requiring soil monitoring and/or ground-water monitoring at land treatment facilities. Commenters favoring inclusion of ground-water monitoring suggested that soil monitoring was limited by its low reliability of detecting highly mobile contaminants and should not be relied upon alone to provide protection to ground water. Others favoring inclusion of ground-water monitoring questioned the Agency's interpretation of when contaminants in the soil constitute a threat to the environment. This criticism was based on the proposed requirement

for soil monitoring at land treatment facilities which automatically required corrective action when contaminants migrated to three times the depth of the zone of incorporation. Commenters felt this requirement to be arbitrary and stifling to land treatment facility operations because it precluded using the full capacity of the soil to attenuate the waste. Commenters suggested that soil monitoring be used to trigger a more comprehensive analysis of environmental harm, particularly ground-water contamination.

The Agency, after evaluating concerns of commenters over protection of ground-water resources at land treatment facilities, recognizing that existing facilities may have already impacted ground water, and realizing the difficulties associated with interpreting soil monitoring results, has decided to require ground-water monitoring at land treatment facilities. Soil and ground-water monitoring, along with leachate monitoring (as previously described in this document) at land treatment facilities will provide a clear definition of any threat to the environment posed by land treatment and the potential to utilize more of the soil's attenuative capacity. Such feedback on facility performance will enable the owner/operator to more effectively manipulate operating parameters in order to optimize facility performance (e.g., waste application rates and pH controls). The Agency believes that the monitoring approach for land treatment facilities as required in the final regulations will not only provide comprehensive knowledge of facility performance but will also enhance ground-water protection.

Commenters who opposed ground-water monitoring at land treatment facilities pointed to a lack of data on adverse ground-water impacts and also felt that the proposed siting and surface controls would offer added protection of ground water.

The Agency believes that the human health and environmental risks stemming from undetected ground-water contamination justify the requirement of ground-water monitoring at land treatment facilities.

These final regulations for ground-water monitoring at hazardous waste facilities under interim status are not applicable until one year after the effective date of these regulations. One year has been provided since the proper installation of a GWMS requires a significant investment in time and money with careful planning by experts (e.g., trained hydrogeologists) to determine appropriate well locations, depths, etc. The anticipated demand for and possible shortage of qualified hydrogeologists to perform such work was also considered by the Agency in providing this time.

The final interim status rule states:

§265.90 (a) Within one year after the effective date of these regulations, the owner or operator of a surface impoundment, landfill, or land treatment facility which is used to manage hazardous waste must implement a ground-water monitoring program capable of determining the facility's impact on the quality of ground water in the uppermost aquifer underlying the facility, except as §265.1 and paragraph (c) of this Section provide otherwise.

Demonstration of acceptability of a lesser degree of (or no) ground-water monitoring. Several commenters favored less stringent

or other conditions than those of the proposed "Note" for demonstrating that a lesser degree of (or no) ground-water monitoring would be acceptable. Factors which commenters believed should be evaluated in such a demonstration include: geologic and hydrologic conditions of the facility area, status of the underlying ground water, nature of the waste, expense of monitoring, facility design, and the state-of-the-art of ground-water monitoring technology.

Commenters felt that lesser or no monitoring should be acceptable if there was "no reasonable potential" or a "low potential" for contamination of ground water (e.g., in dry areas with deep pressurized aquifers).

In considering such comments, the Agency agrees that the provision in the "Note" of the proposed regulations which based acceptance of no or a lesser degree of ground-water monitoring on "no potential for discharge to ground water" is inappropriate and has revised this requirement. Instead, in the revision, if the owner/operator can demonstrate that hydrogeologic conditions underlying the facility and other conditions indicate a low potential for migration of hazardous waste or hazardous waste constituents from the facility via the uppermost aquifer to water supply wells or to surface water, a lesser degree of ground-water monitoring may be utilized (i.e., reduced requirements from those specified in this Subpart). This revision results from the basic technical problem that an owner/operator may be unable to demonstrate conclusively that no potential for discharge

exists. However, he may be able to demonstrate a low potential for ground-water pollution.

The revised approach is not intended to weaken the objective of these regulations. The Agency recognizes, however, that certain hydrogeologic, climatic and other factors reduce the threat of leachate being generated or ground water being impacted. In these situations reduced monitoring may be warranted. Examples of such cases may be found in parts of southwestern United States where the water table is very deep and geologic materials in the unsaturated zone are of low hydraulic conductivity. However, in most other parts of the United States, a facility will be expected to monitor ground-water as described in this Subpart.

The demonstration that a lesser degree of monitoring is warranted, now, must be certified by a qualified geologist or geotechnical engineer. This is to provide an assurance that the complicated issues involved in predicting the migration of constituents in ground water will be addressed by experts in the field. The factors which must be addressed in evaluating whether a lesser degree of ground-water monitoring is warranted are described below. Each factor is discussed with regard to its relevance in making such an evaluation. There is no attempt in this section to develop a scheme for measuring the potential for ground-water pollution or for contamination of water supply wells.

Geologic and hydrologic conditions of the facility area. A thorough hydrogeologic investigation of the characteristics of both the saturated zone and the unsaturated zone is required. The properties of both these zones influence the rate contaminants will migrate and the degree to which contaminants will be attenuated in the subsurface. Hydrogeologic factors must be considered through evaluations of logs of test borings made by a geologist present during drilling. Any other appropriate evidence such as geophysical data may also be used in the evaluation. The Agency believes that a geologist should be present during drilling since he is best qualified to interpret the nature of the subsurface materials encountered in the borings, especially since such materials often cannot be obtained in such a manner (i.e., intact over the full core thickness) so as to perform such observation at an off-site laboratory. Such interpretation is an active field procedure, in which a geologist observes and records pertinent information about the earth materials being removed. This information includes: general description of the material (e.g., clay, sand, silt, -- relating to particle size); abrupt changes in materials (interfaces); or gradations from one material to another. Several methods are available for evaluating and weighing the potential for ground-water pollution based on the characteristics of these zones.[28,55] Also, review of these and other techniques, their advantages and disadvantages, is given by Roy F. Weston, Inc.[71]

A water balance assessment should be made to establish if a lesser degree of monitoring is warranted. Measurements of precipitation, evapotranspiration, runoff and infiltration enable one to establish how much water infiltrates the waste. This in turn influences the amount of leachate that could be generated at the facility.

The water balance, as developed in the soil and water conservation literature, is based upon the relationship among precipitation, evapotranspiration, surface runoff, and soil moisture storage. Precipitation represents that amount of water added. Evapotranspiration, the combined evaporation from the plant and soil surfaces and transpiration from plants, represents the transport of water from the earth back to the atmosphere, the reverse of precipitation. Surface runoff represents water which flows directly off the area of concern. The soil moisture storage capacity represents water which can be held in the soil.[19]

The location and proximity of water supply wells and the type of water use in the vicinity of the facility should be known. Such considerations are important if waste facilities are within the sphere of influence of a pumping water supply well. In this case, once contaminants have entered ground water, the likelihood of them reaching the water supply is very high.

Status of the underlying ground water. Commenters felt that facilities overlying certain aquifers should be exempted from the ground-water monitoring requirements if the underlying aquifer is

"not usable" and is in a "geologically isolated basin"; if the underlying aquifer has greater than 10,000 parts per million total dissolved solids or is not otherwise "safe for drinking or fresh-water use"; if the underlying aquifer is "saline and non-useful"; if the underlying aquifer is already "grossly contaminated" or used for purposes other than drinking; if the ground water underlying the facility area was not used for domestic or industrial purposes; or if the underlying ground water was "perched" water with low quality and quantity.

In responding to comments on ground-water quality underlying a facility, the Agency believes it would not be in the interest of human health and environmental protection to provide a "blanket" exemption for a facility overlying an aquifer which is not a drinking water supply. Such aquifers may be hydraulically connected with and may serve as a path for contamination to migrate to a drinking water supply at some distance from the facility. Furthermore, an aquifer which is not usable because it is too contaminated may discharge contaminants to surface waters or to water supply wells (not only drinking-water wells), thereby limiting the use of these waters for human purposes, as well as harming aquatic life or wildlife. In order to prevent such adverse impacts, the final regulation requires that the full monitoring requirements of this Subpart be implemented at landfills, surface impoundments and land treatment facilities, unless the owner/operator can demonstrate to the Regional

Administrator that the facility overlies an uppermost aquifer in which there is low potential for migration of contaminants into a drinking water supply, to other water supply wells, or to surface water via that uppermost aquifer. This provision will protect underground sources of drinking water from indirect contamination via an aquifer which is not a drinking water supply and will also protect water supply wells and surface waters from such harmful ground-water discharges.

Nature of the waste. Commenters also recommended that waste characteristics (e.g., solubility and other chemical or physical characteristics) should be used as a basis for determining lesser (or no) ground-water monitoring requirements. A comment received on "special wastes" stated that there is no evidence that special waste disposal practices harm ground water and that any ground-water monitoring requirements for special waste should not be made unless the results of a current EPA study so indicate.

The Agency believes that it is not appropriate, at this time, to base ground-water monitoring requirements on the chemical or physical characteristics of hazardous waste due to a lack of knowledge on the several factors which affect the mobilities of these contaminants in the subsurface environment, including: effects of density of different contaminants in different subsurface earth materials; sorption capacities of subsurface earth materials; and chemical reactions of different contaminants with different subsurface earth materials.

Regarding ground-water monitoring requirements (§250.46 of the proposed regulations) for "special wastes," there is no longer such a category in the final regulations for special wastes pursuant to Section 3004 of RCRA and thus the comment on this matter is irrelevant.

Expense of monitoring. Other commenters felt that the expense of ground-water monitoring offered sufficient justification for lesser monitoring requirements. Some stated that wells would be expensive under certain conditions (e.g., where ground water is several hundred feet deep). Other commenters felt that the monitoring requirements would be too expensive for their particular hazardous waste management operations. As an alternative, one commenter suggested sampling of the "closest drinking water supply" in lieu of installing a GWMS.

The Agency believes that expense of ground-water monitoring should not be a factor for determining the acceptability of a lesser degree of (or no) monitoring. Reducing monitoring requirements based on expense would seriously jeopardize the goal of RCRA to protect human health and the environment. As discussed earlier, the owner or operator is provided in the final regulations an opportunity to demonstrate the acceptability of a lesser degree of (or no) ground-water monitoring based on various factors (e.g., depth to ground water as a hydrogeologic factor and <u>not</u> an expense factor). The commenter's suggestion to use the closest drinking water supply

instead of on-site monitoring wells is not appropriate since only wells located at the limit of the waste management area could detect a contaminant discharge as early as possible, thereby allowing the maximum time to determine the extent of any ground-water contamination and to implement corrective action if appropriate.

Facility design. Facility design was suggested by some commenters as a basis for a lesser degree of (or no) ground-water monitoring, since properly designed facilities are frequently built to retain hazardous wastes.

The Agency believes that for landfills, surface impoundments and land treatment facilities, facility design (i.e., design intent) should not be a basis at this time in determining the acceptability of lesser monitoring requirements, since it has yet to be demonstrated that any given design will positively prevent contaminant discharges.

State-of-the-art of ground-water monitoring technology. One commenter felt that the ground-water monitoring requirements should be deferred pending further research and completion of a comprehensive manual, since at present there is "limited knowledge and dependability" for ground-water monitoring.

The Agency believes that ground-water monitoring requirements should not be deferred since adequate monitoring methodology for detecting contaminant migration has been demonstrated.[2-7,53,54] Deferring these requirements would result in undetected contaminant

discharges, and thus a failure to meet the mandate of Congress to protect human health and the environment. It is also important to note that the Agency is continuously seeking to improve monitoring methodology and will be providing further guidance on this subject in the future.

Owners or operators who perform a lesser degree of (or no) ground-water monitoring at their facilities during interim status must have available for submission, at any time the Regional Administrator so requests, a demonstration that there is a low (or no) potential for migration of hazardous waste constituents to a USDW, to water supply wells, or to surface water via the uppermost aquifer, during the active facility life and post-closure care period.

The final rule for interim status states:

§265.90 (b) Except as paragraphs (c) and (d) of this Section provide otherwise, the owner or operator must install, operate, and maintain a ground-water monitoring system which meets the requirements of §265.91, and must comply with §§265.92-265.94. This ground-water monitoring program must be carried out during the active life of the facility, and for disposal facilities, during the post-closure care period as well.

(c) All or part of the ground-water monitoring requirements of this Subpart may be waived if the owner or operator can demonstrate that there is a low potential for migration of hazardous waste or hazardous waste constituents from the facility via the uppermost aquifer to water supply wells (domestic, industrial, or agricultural) or to surface water. This demonstration must be in writing, and must be kept at the facility. This demonstration must be certified by a qualified geologist or geotechnical engineer and must establish the following:

(1) The potential for migration of hazardous waste or hazardous waste constituents from the facility to the uppermost aquifer, by an evaluation of:

(i) A water balance of precipitation, evapotranspiration, runoff, and infiltration; and

(ii) Unsaturated zone characteristics (i.e., geologic materials, physical properties, and depth to ground water); and

(2) The potential for hazardous waste or hazardous waste constituents which enter the uppermost aquifer to migrate to a water supply well or surface water, by an evaluation of:

(i) Saturated zone characteristics (i.e., geologic materials, physical properties, and rate of ground-water flow); and

(ii) The proximity of the facility to water supply wells or surface water.

Additional issues concerning applicability. One commenter suggested that the ground-water monitoring requirements should serve only as a "guide" for reviewing agencies.

The Agency disagrees with the recommendation of this commenter, since Congress mandated EPA to publish regulations to ensure safe hazardous waste management, not "guides" for reviewing agencies.

A commenter suggested additional monitoring requirements for "extraordinary" geologic or topographic conditions (e.g., Karst areas).

The Agency feels that it is not necessary to specify in the final regulations such additional monitoring requirements since such

potential action is implicit in the final wording. Since these regulations specify minimum monitoring requirements, additional monitoring, e.g., more wells, may be required as deemed appropriate.

One commenter claimed that the "Note" of the proposed regulation stipulating conditions for a lesser degree of (or no) monitoring provided a loophole to escape regulation since conditions in ground water can change after permit issuance.

The Agency recognizes that ground-water quality may change over time. Conditions which must be demonstrated by the owner or operator to justify the acceptability of a lesser degree of (or no) monitoring are rigorous and consider not only hydrogeologic factors but proximity to water supply wells and use of water as well. However, acceptance of lesser monitoring by the Regional Administrator may be redetermined if information indicates that the basis for demonstration is no longer valid. In addition, the "imminent hazard" provisions of Section 7003 of RCRA may be employed in such situations should a serious contamination threat arise.

An additional provision was included in these final interim status regulations which allows for an alternate ground-water monitoring system (other than the one described in §§265.91 and 265.92) to be installed if an owner or operator assumes (or knows) that ground water has been contaminated. This provision enables the owner or operator to bypass the monitoring of indicator parameters and proceed with a more rigorous ground-water monitoring program which would be more specific in its sampling of ground-water quality.

As stated in the regulation, the owner or operator who elects to utilize the alternate ground-water monitoring system will operate under a slightly different monitoring schedule. No later than one year after the effective date of these regulations, the owner or operator will be required to initiate a ground-water quality assessment plan and this more detailed plan (i.e., more detailed than the indicator parameter sampling) will continue on a quarterly basis. The rationale is that these more extensive assessments on a quarterly basis allow for a more in-depth knowledge of the rate, direction and concentration of subsurface contamination.

The final rule for interim status states:

§265.90(d) If an owner or operator assumes (or knows) that ground-water monitoring of indicator parameters in accordance with §§265.91 and 265.92 would show statistically significant increases (or decreases in the case of pH) when evaluated under §265.93(b), he may install, operate, and maintain an alternate ground-water monitoring system (other than the one described in §§265.91 and 265.92). If the owner or operator decides to use an alternate ground-water monitoring system he must:

(1) Within one year after the effective date of these regulations, submit to the Regional Administrator a specific plan, certified by a qualified geologist or geotechnical engineer, which satisfies the requirements of §265.93(d)(3), for an alternate ground-water monitoring system;

(2) Not later than one year after the effective date of these regulations, initiate the determinations specified in §265.93(d)(4);

(3) Prepare and submit a written report in accordance with §265.93(d)(5);

(4) Continue to make the determinations specified in §265.93(d)(4) on a quarterly basis until final closure of the facility; and

(5) Comply with the recordkeeping and reporting requirements in §265.94(b).

3. Ground-Water Monitoring System

Synopsis of Proposed Regulation

The proposed regulations required the owner/operator of a landfill or surface impoundment to install, maintain and operate a ground-water monitoring system (GWMS). This system was to consist of a minimum of four monitoring wells with at least one well located hydraulically upgradient from the active portion of the facility to obtain representative background samples. A minimum of three wells was required to be installed hydraulically downgradient of the active portion of the facility. At least one of the downgradient wells was to be located immediately adjacent to the active portion of the facility, while the others were to be located within the facility property, to provide the greatest opportunity for interception of any leachate migrating from the facility into ground water. Downgradient wells were to be drilled to different depths to detect any leachate migration into ground water beneath the facility. Each well was to be constructed to draw samples from those depths where the facility owner/operator could demonstrate that contamination was most likely to occur. In addition, a "Note" contained a provision to allow wells to be drilled to a single depth if the owner/operator could demon-

strate that this was the depth at which contamination was most likely to occur.

All monitoring wells were required to be cased, and the annular space backfilled with an impermeable material to prevent surface water from entering the well bore and inter-aquifer water exchange. This section of the ground-water monitoring requirements (i.e., well number, location and construction) were not proposed for facilities under interim status since only those facilities with monitoring systems in place were required to comply. However, since these requirements have been incorporated into these final rules, this section of the proposed regulations is discussed.

Rationale for the Proposed Regulation

The objective of the proposed GWMS was to detect any ground-water contamination caused by leachate migrating from a facility. Wells would be strategically located relative to ground-water flow direction and would be sampled at regular intervals to detect changes in concentrations of chemical constituents in the ground water.

3a. Number of Monitoring Wells

Synopsis of Proposed Regulation

The proposed regulation required a GWMS consisting of a minimum of four monitoring wells, with at least one well upgradient of the active portion of the facility and at least three wells downgradient of the active portion.

Rationale for the Proposed Regulation

The number of monitoring wells required was site-specific with large sites, or sites in complex hydrogeologic settings requiring a greater number than a small site or a hydrogeologically simple site. If the geologic setting of the facility area was not complex, and the ground-water flow direction was accurately defined, the minimum requirement of four wells was considered to be adequate.

The proposed four-well minimum requirement was determined through review of available literature and through discussions with knowledgeable organizations in ground-water monitoring.

Fenn et al., recommended a minimum monitoring system consisting of: one upgradient well to sample background ground water, unaffected by the waste management activity; a line of three downgradient wells between the waste management activity and facility property boundary and perpendicular to ground-water flow; and another downgradient well located immediately adjacent to the waste management activity.[18]

The system recommended by Mooij et al., called for wells both on and off the facility property as follows: the wells within the facility property would include one upgradient and two downgradient of the waste management activity (with one downgradient well at the facility property boundary and the other downgradient well between the property boundary and the waste management activity); the "off-site" wells, one upgradient and one downgradient, would be the

nearest water supply wells (not necessarily hydraulically connected to the wells within the facility property).[36]

The Texas Water Quality Board (TWQB), in its 1976 guidelines, recommended one upgradient well and two downgradient wells (all within the facility property), with one downgradient well closer to the waste management activity than the other downgradient well.[59] In discussions with the TWQB, EPA learned that the TWQB has issued a draft of new guidelines which would recommend a minimum GWMS of four wells.[58]

After reviewing information on various GWMSs, the Agency felt that four wells would be satisfactory for a minimum GWMS. All wells would be located within the facility property boundary to ensure early detection of any contaminant migration. One upgradient well was considered by the Agency to be necessary to monitor uncontaminated ground water as did those persons recommending other GWMSs. Although other systems recommended two, three, or four downgradient wells, the Agency felt that three would be an adequate minimum for the simplest monitoring situations.

Comments Received/Rationale for Chosen Action

Commenters addressed the adequacy of the four-well minimum monitoring requirement, with some favoring more or fewer wells, while others agreed with the proposed requirement. Commenters offered various rationales for determining an adequate number of monitoring wells including: size of the facility area to be monitored; geology

and hydrology of the facility area; use of pre-monitoring information on the facility area; configuration of the waste management area; number of waste management components in a facility; and waste characteristics.

In regard to the size of the area to be monitored, some commenters felt that the four-well minimum requirement was not adequate to monitor large areas or was not functionally adequate with respect to area (e.g., the number of wells should be in proportion to acres to be monitored, such as one well per five acres). Commenters also recommended spacing requirements for downgradient wells (e.g., one well every 500 feet with variances due to site geology).

The Agency agrees with commenters in believing that the size of the facility area to be monitored is an important factor in determining the number of monitoring wells necessary to adequately monitor ground water at a facility. The proposed requirement did consider concerns over this factor, since the requirement called for a minimum of four wells. This minimum requirement is retained in the final regulations. The Agency believes this to be a flexible approach. Furthermore, the Regional Administrator may accept fewer than four wells if the owner/operator can demonstrate that there is a low (or no) potential for ground-water contamination as explained in the discussion on applicability. The Agency does not agree with comments concerning the determination of monitoring well number based on a strict well to acre proportion or with specified equal spacings

between downgradient wells. Such formulae do not provide the flexibility to accommodate site-specific factors and may result in a failure to detect a contaminant discharge through inappropriate well location and number (e.g., a facility with multiple waste management components may have distances between these components greater than 500 feet; or in a small site with complex hydrogeology, a prescribed well per acre ratio may result in too few wells).

Some commenters felt that the number of monitoring wells should be determined by site-specific geologic and hydrologic conditions, such as ground-water flow direction, permeabilities of subsurface materials, depth to ground water, and amount of precipitation. One commenter felt that only one downgradient well was initially adequate to detect leachate migration in dry areas with deep ground water, maintaining that additional downgradiant wells could be required if contamination appeared in the initial downgradient well. Another contended that only one downgradient well would be needed in areas having natural clay liners, allowing the Regional Administrator discretion in requiring more wells. Still another commenter believed that an "absolute requirement" for four wells was arbitrary since the purpose of the GWMS is to monitor each dominant flow direction and this could be done by more or fewer than four wells.

The Agency agrees with commenters who believe that site-specific hydrogeology is an important factor in determining an adequate number

of monitoring wells. Concerning comments that one downgradient well would be sufficient for dry areas with deep ground water or in sites with natural clay liners, the final regulations provide the owner/operator with the opportunity to demonstrate to the Regional Administrator that a lesser degree of monitoring would be acceptable.

The Agency is aware of no hydrogeological justification or protocol, either from public comments or any other information sources, which adequately refutes the four-well minimum requirement. This minimum has been determined by the Agency to be the least number of wells needed to detect a contaminant discharge under the simplest of conditions. The Agency, in maintaining the four-well minimum requirement in these final regulations, still believes that at least one well upgradient of the waste management area is needed to ensure detection of a contaminant discharge. The final regulations require that the downgradient wells be located at the limit of the waste management area. One downgradient well located at the limit of the waste management area may be sufficient to detect a contaminant discharge which is in line with ground-water flow toward that well. However, a discharge may occur to either side of this well and such contamination may go undetected. Therefore, the final regulations require at least two more wells at the limit of the waste management area, installed such that they are on opposite sides of the first well. The Agency anticipates that many facilities, because of hydrogeologic and/or other factors such as large area, will be required to

install more than three downgradient wells to ensure contaminant detection. Based on this approach, the Agency disagrees with commenters stating that the four-well minimum requirement is arbitrary. In addition, the requirement is highly dependent on ground-water flow direction, as further explained in the discussion on well location.

A commenter felt that "pre-monitoring" information on a facility should also be a factor in determining the number of wells.

The Agency agrees with this commenter that any valid data about the facility area should be used by the owner/operator in developing a GWMS.

Commenters believed that the number of waste management components within a facility and the configuration of the disposal area are factors which should be considered in determining the number of monitoring wells. Some stressed that a common set of monitoring wells should be allowed for a facility with multiple waste management components, while one commenter stated that the four-well minimum requirement could be inadequate at such a facility.

The four-well minimum requirement of these final regulations applies to facilities regardless of the number of waste management components in the facility or the configuration of the waste management area. In the case of a facility with multiple waste management components, the monitoring-well system must ensure detection of a discharge from any component. Thus, in some cases more than four wells may be required.

Commenters stated that waste characteristics, such as "degree of hazardousness," should be considered in determining the number of monitoring wells.

The Agency sees no valid reason for requiring well number to be a function of waste characteristics, nor did commenters provide a rationale. Waste characteristics that would be relevant to a "degree of hazard" scheme are not relevant to the number of wells in the GWMS, where the key concern is the system's capacity to detect discharges into ground water.

One commenter suggested replacing the four-well minimum requirement with a requirement for a "suitable number" of wells.

As previously stated, the Agency feels that the minimum requirement provided in the final regulations provides the flexibility needed to meet the concern of this commenter.

Another commenter expressed concern that the proposed requirement that at least one of the downgradient wells be located immediately adjacent to the active portion of the facility could result in the installation of additional wells since the active portion of a landfill constantly moves. The commenter also suggested deleting reference to "active face."

In the proposed regulation it was not the Agency's intention to require monitoring wells at the edge of the active portions of a landfill, with periodic relocation of these wells once the boundary of the waste had been extended. It was assumed in the proposed

regulations, and still is in these final interim status regulations, that the wells would be located at the waste boundary which will exist upon completion of the facility.

3.b. Monitoring Well Location

Synoposis of Proposed Regulation

The ground-water monitoring system in the proposed regulations required a minimum of four wells to assure detection of any contaminants entering ground water from the facility. The location of at least one well was required to be hydraulically upgradient from the active portion of the facility so as to yield samples representative of the background quality of the ground water which flows under the facility. A minimum of three wells were required to be located hydraulically downgradient of the active portion of the facility. The placement of the downgradient wells was further specified in the regulation. One of these three wells was required to be located immediately adjacent to the active portion of the facility and the other wells were to be located within the property boundary of the facility to provide the opportunity for interception of any leachate that migrated into ground water underlying the facility.

Rationale for the Proposed Regulation

At least one well was required to be located hydraulically upgradient of the active portion of the facility so as to obtain background ground-water samples, i.e., unaffected by facility activities. A minimum of three wells was required to be located hydraulically

downgradient of the active portion of the facility. One of the downgradient wells was required to be immediately adjacent to the site in order to detect the leachate entering the ground water. The other downgradient wells were required to be located within the property boundary of the facility in order to detect the leachate plume as soon as possible. The rationale was that once leachate enters the ground water, it is difficult to control; the sooner its presence is noted, the easier it will be to initate remedial action.

Comments Received and Agency Response

The comments as to the exact placement of the monitoring points were varied. The most frequent comment received concerned the allowance of a flexible approach to ground-water monitoring. The majority of comments addessed the location of downgradient monitoring wells only. Placement of the upgradient wells was not a major issue. With regard to well placement specifically, the major comment was that monitoring wells should not be located at the edge of the waste. One rationale was that it was unnecessary because leachate monitoring was also required in the proposed rule. The major contention was that the leachate monitoring system will detect failures in the containment system prior to contaminants reaching the ground water at the active edge of the waste, thus precluding the need for a monitoring well at the active edge of the waste.

A major problem with this approach is that if leachate monitoring failed to detect contamination migrating from the facility, the

absence of monitoring wells would allow contamination to flow undetected in ground water. The possibility of this occurring is discussed in the leachate monitoring section where the inadequacy of leachate monitoring technology is established. Further since leachate requirements have been deleted from the final regulations, this comment is no longer valid.

A second rationale for not locating monitoring wells at the edge of the waste was that such wells may promote leachate movement to ground water, since leachate movement in active portions is lateral, not vertical. The suggestion was to locate the monitoring point at some meaningful distance between the active portion and the site boundary.

The major reason for this commenter's suggestion is the assertion that leachate movement in the active portions is lateral, not vertical. These regulations require that the monitoring wells be properly constructed so as to prevent surface water or water in the unsaturated zone from migrating down the annular space of the monitoring well. Such prevention can be accomplished by backfilling the space between the casing and the bore hole with material of very low permeability. Because of this, and the fact that the wells will be located at some reasonable distance from the boundary of the waste management area, to allow installation, the likelihood of monitoring wells located at the edge of the waste boundary being conduits for contaminant migration to the ground water is very unlikely. However,

these construction techniques should not be interpreted as being suitable for installing monitoring wells through the facility. Such practices, if applied to existing facilities, increase the possibility of contaminants entering the aquifer during drilling operations. Technologies for new facilities do not resolve the problem of leachate head buildup around wells installed through the facility. Such head buildup increases the likelihood of contaminants migrating through the annular space and into ground water. This head build up should not be a factor for wells located at the edge of the waste management area.

Commenters suggested that the proposed wording on well locations be deleted and replaced with general wording which requires wells to be located so as to yield samples representative of the background quality of the ground waters which flow under the facility and to detect any leachate which has migrated into ground waters underlying the facility property. The commenter's rationale for the change is that it provides more flexibility. The recommended approach for well location should be goal-oriented, allowing the owner/operator to provide monitoring data and to use his own discretion in choosing well location. A similar comment recommended adding the statement that "monitoring systems shall be designed and constructed to draw representative samples from the zones in the ground-water system which are representative of those zones most susceptible to endangerment, and to detect contamination as soon as possible." The commenters

contended that to use the proposed requirement could result in ineffective ground-water monitoring.

These comments encourage more owner/operator discretion in placement of the monitoring wells. In implementing the goal of detecting contaminants as soon as possible after entering ground water, there is little alternative but to place the monitoring well at the boundary of the waste management area. Placing monitoring wells through the facility is discouraged because this increases the likelihood of contaminants entering ground water via migration down the annular space between the well casing and the borehole. Any approach that would allow for the possible location of the wells to be some distance from the waste management area (as could happen when left up to owner/operator discretion) would not allow for earliest possible detection of contamination.

Rationale for Chosen Action

The required location of the upgradient well is unchanged from the proposed rule. The required location of the downgradient monitoring wells has been changed in the final regulations. Since leachate monitoring of the unsaturated zone at landfills and surface impoundments has been deleted from the final regulations because of technical problems with such systems, the most protective alternative is to monitor at the boundary of the waste management area.

This alternative is preferred over monitoring ground water directly beneath the facility. Such monitoring would, in most cases,

require the installation of monitoring wells through the waste and into the underlying ground water. This practice is discouraged by the Agency since the installation of such a system in existing facilities is likely to provide a direct conduit for migration of contaminants to the ground water. The nature of pollutant mobility and ground-water flow is such that a facility which causes groundwater contamination consistently beneath the facility will eventually cause the ground water at the downgradient waste management area boundary to be contaminated.

Placing monitoring wells at the edge of the waste management area as opposed to some distance away (e.g., at the property boundary) allows for early detection and possible remedy of the problem.

For these reasons, in the final regulations ground-water monitoring wells must be located at the downgradient edge of the waste management area. They must be located and completed such that they will detect any contamination migrating from beneath the waste management area.

In the case of land treatment facilities, however, the Agency believes that leachate monitoring (i.e., soil pore water monitoring) is both desirable and technically feasible, even at existing facilities. Such monitoring can provide valuable information on the effectiveness of the land treatment processes occurring in the soil in retaining leachate constituents in the unsaturated zone material.

Leachate monitoring at these facilities can also indicate if leachate is migrating toward the saturated zone (i.e., toward ground-water). This type of monitoring at land treatment facilities would be accomplished through the emplacement of lysimeters in the unsaturated zone directly beneath such facilities. Unlike placement of monitoring wells, drilling and installation of lysimeters would not penetrate into the ground water, thus alleviating the concern that a continuous boring from the land surface down to ground water could act as a conduit for contamination. The Agency also believes it is appropriate and requires monitoring wells at the perimeter of land treatment areas, in the same manner as for landfills and surface impoundments, to determine whether ground water is being impacted by land treatment activities.

3.c. Well Depth

Synopsis of Proposed Regulation

The proposed regulations required that the upgradient well(s) be installed so as to yield samples representative of background quality of ground water which flows under the facility. The downgradient wells were to be sunk to different depths to detect any leachate migrating from the facility into ground water, with each well being constructed to draw samples from depths where the facility owner or operator could demonstrate that contamination is most likely to occur.

Furthermore, the proposed regulations contained a "Note" allowing wells to be sunk to a single depth if the owner or operator could demonstrate that this was the depth at which contamination was most likely to occur.

Rationale for the Proposed Regulation

The proposed regulations required the upgradient well(s) to be installed to obtain samples representative of ground water potentially affected by a discharge from a facility. The requirement that the downgradient wells be sunk to different depths where contamination is most likely to occur was based on the physical behavior (e.g., density) of contaminants as related to sampling of different vertical levels within an aquifer. For example, oily leachate would float on top of ground water. If the physical behavior of a contaminant is not fully known, it is difficult to anticipate the depth at which a contaminant will flow within an aquifer. Therefore, the proposed requirement specified that the downgradient wells be installed at different depths.

The "Note" gave the owner or operator an opportunity to install wells at a single depth if he could demonstrate that contaminants migrating from a facility would assume a specific depth within an aquifer. Such an exception would require detailed knowledge by the owner/operator of the aquifer and waste behavior within the aquifer.

Comments Received and Agency Response

A commenter recommended that maximum depths for drilling into bedrock and the minimum depth for drilling into ground water be specified.

The Agency believes that it is not appropriate or feasible in the requirement to specify well depths to ensure contaminant detection. Determining appropriate well depths is a site-specific process and depends on various factors (e.g., depth to ground water and contaminant behavior in the aquifer). The Agency will offer, in the future, guidance on monitoring well depths.

Concerning the single-depth provision of the "Note," one commenter felt that such a provision was a regulatory loophole. The Agency believes that the proposed provision did not constitute a regulatory loophole since the owner or operator was required to demonstrate that contamination was most likely to occur at that depth. However, the single-depth provision has been deleted in the final regulations since the final wording relates well depth to the performance goals of the wells.

Commenters did not specifically address upgradient wells with respect to depth. However, the Agency has revised the proposed wording to more clearly express that depth and surface location must both be considered in accomplishing the objective of the upgradient well.

Commenters addressed various aspects of downgradient wells with respect to depth. One felt the requirement that downgradient wells

be "sunk to different depths" should be changed to "drilled to appropriate depths" to reflect common terminology. The Agency agrees conceptually and has rewritten the proposed requirement to more clearly emphasize that depths of downgradient wells should be related to their performance objective, that is, to ensure detection of contaminant migration from a facility.

Also, a commenter felt that it is not always necessary to monitor at three different depths when the facility overlies a sole source aquifer if one downgradient well is located immediately adjacent to the active portion of the facility and is designed to detect leachate in the shallowest aquifer. Furthermore, the commenter claimed that the single-depth provision of the proposed "Note" supported his position.

The Agency believes that downgradient wells, whether in a sole source or other aquifer, may be installed at the same or different depths, depending on site-specific conditions. However, the Agency disagrees with the commenter's rationale that only one downgradient well is sufficient to detect contamination, for reasons stated in the discussion on well number. Furthermore, the single-depth provision of the proposed "Note" did not imply that <u>one</u> downgradient well at the depth where contamination was most likely to occur would be sufficient to ensure contaminant detection.

Finally, a commenter felt that for downgradient wells, determination of the "subsurface elevation" at which contamination is most likely to occur should be made by state or local authorities and the

operator to prevent abuse by the operator. The Agency maintains that the responsibility to determine well depths lies with the facility owner/operator.

Rationale for Chosen Action

The Agency has revised the proposed wording on depth of monitoring wells in order to reflect more common technical terminology and to clarify the relationship between well depth and performance objectives.

Therefore, the final interim status rule for monitoring well number, location and depth states:

§265.91(a) A ground-water monitoring system must be capable of yielding ground-water samples for analysis and must consist of:

(1) Monitoring wells (at least one) installed hydraulically upgradient (i.e., in the direction of increasing static head) from the limit of the waste management area. Their number, locations, and depths must be sufficient to yield ground-water samples that are:

(i) Representative of background ground-water quality in the uppermost aquifer near the facility; and

(ii) Not affected by the facility; and

(2) Monitoring wells (at least three) installed hydraulically downgradient (i.e., in the direction of decreasing static head) at the limit of the waste management area. Their number, locations, and depths must ensure that they immediately detect any statistically significant amounts of hazardous waste or hazardous waste constituents that migrate from the waste management area to the uppermost aquifer.

(b) Separate monitoring systems for each waste management component of a facility are not required provided that provisions for sampling upgradient and downgradient water quality will detect any discharge from the waste management area.

(1) In the case of a facility consisting of only one surface impoundment, landfill, or land treatment area, the waste management area is described by the waste boundary (perimeter).

(2) In the case of a facility consisting of more than one surface impoundment, landfill, or land treatment area, the waste management area is described by an imaginary boundary line which circumscribes the several waste management components.

3.d. Buffer Zone for Ground-Water Protection

Synopsis of Proposed Regulation

The proposed regulation required that the active portions of hazardous waste facilities be located a minimum of 60 meters from the property line of the facility, unless it could be demonstrated that unexpected releases or discharges of hazardous wastes could be controlled before they cross the facility property boundary.

Rationale for the Proposed Regulation

The purpose of setting a minimum distance which the active portion of a facility could be located from its boundary line was to provide a buffer zone between the public and the facility. The Agency believes that buffer zones reduce risks to public health and the environment by allowing unexpected discharges resulting from fires and explosions to dissipate, and for spills and underground leaks to be contained or to dissipate before crossing the property

boundary. In addition, buffer zones can be used for aesthetic purposes, such as noise reduction or screening of facilities in order to preserve natural appearances.

The section of 60 meters (200 feet) from the facility's boundary line as the required width of the buffer zone was based on the following:

> The State of Oklahoma prohibits disposition of industrial waste within 200 feet of the permit boundary, thus providing a precedent of the proposed RCRA regulation. Although other states have narrower width requirements for buffer zones (e.g., Wisconsin-20 feet; Pennsylvania-25 feet; and New York-50 feet), these regulations only pertain to municipal solid waste. Since hazardous waste poses a greater risk to public health and the environment than municipal solid waste, Oklahoma's more stringent regulation for industrial waste was adopted.

A fixed distance was specified in order to facilitate enforcement and to provide a tangible point of reference.

Comments Received and Agency Response

Most commenters responded to the 60 meter buffer zone as it applied categorically to all risks (i.e., fires, explosions, underground leaks, etc.). Only a few singled out ground water when commenting on the adequacy of the 60 meter buffer zone. Nearly all of the comments regarding the buffer zone requirement were against the specification of a discrete distance in the standard because of the many factors (type and size of the facility, nature of waste handled at the facility, type of land use surrounding the facility, operating and safety procedures utilized at the facility, hydrogeologic conditions beneath the facility) which influence the size of the buffer zone that is needed at a facility.

The few commenters who discussed the adequacy of the 60 meter buffer zone with regard to ground-water protection were all in favor of increasing the distance. Some commenters stated that facilities should not be located in population centers because leachate from chemical landfills may travel more than 200 feet in porous soil and contaminate public or private wells.

Other commenters stated that the standard should require a 300 foot buffer zone. This suggestion was based on data derived from the lateral subsurface migration of septic tank effluents.

While EPA believes that buffer zones may be an important component of a ground-water protection strategy, the Agency is not prepared to establish specific buffer zone requirements for such a purpose at this time. This issue will be examined as part of the Phase II regulations. This issue raises several key technical questions (e.g., transport and fate of contaminants in the subsurface) which need further analysis.

3.e. Well Casing and Backfilling

Synopsis of Proposed Regulation

The proposed regulations required all monitoring wells to be cased and the annular space backfilled with an impermeable material to prevent surface water from entering the well bore and interaquifer water exchange. "Annular space" was defined to mean the space between the bore hole and the casing.

Rationale for the Proposed Regulation

The objective of the proposed requirement for casing and backfilling of monitoring wells was to ensure that representative samples of ground water were obtained from the appropriate depths and that the samples would not be contaminated by surface water infiltration down the well bore or by interaquifer exchange of ground water.

Comments Received and Agency Response

A commenter felt that "casing" should be clarified to refer to a well pipe to withdraw samples rather than an open hole. Furthermore, this commenter believed that monitoring-well casing, as described in the proposed requirement, could be confused with casing which is used to prevent hole cave-in during drilling.

The Agency believes that it was clear in the proposed requirement that casing did not refer to an open hole, but to well pipe installed to the appropriate depth to obtain ground-water samples. Also, the Agency feels that it was clear in the proposal that casing referred to monitoring-well casing and not to casing used to maintain the structure of the bore hole during drilling. Monitoring-well casing does, of course, assure the integrity of the well so that monitoring in the future may continue. The final requirement makes clear this purpose.

A commenter stated that monitoring-well construction as described in the proposed requirements would probably not provide representative samples, if any. The commenter further stated that well

installation should include gravel pack and perforated casing at levels to be sampled.

In response to the concerns of this commenter, the Agency has clarified the wording of the proposed regulation to ensure that representative ground-water samples will be obtained from appropriate aquifer flow zones. A requirement that well casing be screened or perforated where necessary is included in the final regulation since not all well casings would require such a procedure. For example, a casing with an open hole at the bottom may be sufficient in certain types of aquifers, such as fracture and solution channels, provided that the well was properly developed. In addition, gravel or sand packing must be installed where necessary around the area of screened or perforated casing in those situations where clogging by aquifer materials would occur. The Agency believes this to be technology which is common knowledge in well-drilling procedures.

Another commenter stated that the Agency should recognize that certain wells drilled in bedrock formations should only be cased and cemented into the top of the bedrock and that the remaining bore hole is typically left uncased.

Although the Agency recognizes that ground-water samples may be obtained with only partial casing in certain bedrock formations, the final regulation requires casing to be installed throughout to enable sample collection at depths where appropriate aquifer flow zones exist, even in bedrock formations. This ensures that casing will

extend to the desired sampling depth that will ensure detection of contaminant migration from a facility, and enable cementing of the annular space between the casing and bore hole.

Comments received also questioned the use of the word "impermeable" in regard to the backfilling material requirement of the proposed regulations, suggesting that no backfill material is truly impermeable. Also, use of the term "highly impermeable" was suggested as a remedy by one commenter.

The Agency agrees with commenters that the literal meaning of the word "impermeable" is not accurate for backfill materials. Such materials must, however, have very low permeabilities. Therefore, the Agency has modified the requirement such that the final wording emphasizes the intended performance goal of preventing contamination of samples and the ground water by backfilling the annular space with a suitable material.

Rationale for Chosen Action

The final regulations for well casing and backfilling have been rewritten to clarify any misunderstanding created by the proposed regulations. Terminology commonly used by well drillers, such as "screened" and "sealed," has been incorporated. Emphasis of the goal has been clarified.

The final interim status rule states:

§265.91(c) All monitoring wells must be cased in a manner that maintains the integrity of the monitoring well bore hole. This casing must be screened or perforated, and packed with gravel or sand where necessary, to enable sample

collection at depths where appropriate aquifer flow zones exist. The annular space (i.e., the space between the bore hole and well casing) above the sampling depth must be sealed with a suitable material (e.g., cement grout or bentonite slurry) to prevent contamination of samples and the ground water.

4. Sampling and Analysis

Synopsis of Proposed Regulation

The proposed regulations required periodic sampling and analysis for both a comprehensive and a routine list of characteristics and constituents following establishment of background ground-water quality. For an existing facility background quality was to be established by monthly sampling and analysis for a period of one year. A comprehensive analysis list was used to establish initial background water quality, and to monitor any changes in background quality annually. A shorter routine list of analyses was to be performed semiannually if the ground-water flow rate was between 25 and 50 meters/year (82 and 164 ft/year) or quarterly if the ground-water flow rate was greater than 50 meters/year (164 ft/year).

The comprehensive analysis list included at least 39 ground-water quality characteristics including: the EPA Primary and Secondary Drinking Water Regulations' constituents and characteristics (except radioactivity); beryllium, nickel, cyanide, phenolic compounds and organic constituents as determined by gas chromatography scanning; and the characteristics of the minimum or routine analysis list. This routine analysis list included specific conductivity, chloride, total dissolved solids (TDS), dissolved organic

carbon, and the principal hazardous constituents disposed in the facility. A "Note" in the proposed regulations allowed deletion from the comprehensive analysis list those characteristics that would not result from hazardous waste managed at the facility, once background levels had been established.

Rationale for the Proposed Regulation

The intent of the ground-water monitoring program as an integral component of a hazardous waste management facility was to serve as a backup system in the event of failure of the facility to adequately contain the wastes. Both the frequency and types of analyses specified would provide failure so that remedial action could be taken to eliminate or reduce environmental contamination.

The analyses made of samples taken from the monitoring system should be sufficiently sensitive to determine statistically significant changes in ground-water quality resulting from leakage from a hazardous waste management facility. In addition, the selected analyses should be sensitive to the levels of contamination associated with land disposal and should be capable of detection in a reliable manner which minimizes the time required for sampling and analysis.

Because the proposed facility standards prohibited "endangerment" (causing the ground water to require increased treatment), the monitoring requirement included many contaminants for which treatment is required when their concentrations exceed Agency-specified levels.

Thirty-one of the listed characteristics came from the EPA drinking water regulations (40 CFR 141 and 143). The Agency realized that the list was not inclusive of all contaminants for which treatment would be required. A variable frequency of monitoring was included in the proposal in recognition of differing rates of ground-water flow in different areas. More frequent monitoring was required in high ground-water flow rate areas to better assure early detection of contamination.

Comments Received and Agency Response

Sampling Frequency. Only a few comments were received regarding the specified frequencies of routine monitoring after establishing background water quality. Most agreed that monitoring frequency should be related to ground-water flow rates but also urged Agency flexibility. The Agency now, for facilities in interim status, requires at least semi-annual ground-water sampling for certain "indicator" parameters and at least annual sampling for other specified water quality parameters, as described later. The Agency believes that these frequencies will provide adequate data to evaluate any significant changes in ground-water quality over time.

Background Water Quality. Every commenter who addressed the issue of obtaining 12 samples at monthly intervals to determine background water quality felt that this requirement should be relaxed. The Agency agrees that in many cases this frequency is unnecessary, but it also feels that obtaining representative background data at a

reasonably frequent interval during the first year is critical to the success of the overall monitoring program. Thus, the Agency is revising the proposed regulation to require quarterly samples during the first year and feels that this interval is sufficient to obtain statistically valid data, incorporating seasonal and other unpredictable variations.

Representative background water quality data is essential to the success of the ground-water monitoring program. The list of background water quality parameters must provide a reasonably broad base for comparing current water quality in the event of a need to perform a further assessment of facility impact on ground water; yet, it cannot be so extensive that it is neither reasonable nor cost effective. It is in the best interest of the owner or operator to accurately assess background water quality because overstating it would unnecessarily trigger the need for a much more extensive ground-water quality assessment, while understating background quality would unduly delay the triggering of a ground-water quality assessment which, in turn, could be more costly to clean up.

Sampling and Analysis Protocol. Two commenters recommended that specific protocols should be included for ground-water sampling, sample preservation and methods of analysis. The Agency had intended in the proposed regulation that the guidelines for these methods and others would be provided by guidance documents rather than formalizing them into the regulatory framework. This would give the owner or

operator the latitude of choosing a particular method from several generally accepted or equivalent methods. In deference to these comments, however, the final regulations have been revised to include reference to the Agency's suggested publications: "Methods for Chemical Analysis of Water and Wastes," EPA-600/4-79-020, March 1979, and "Procedures Manual for Ground-Water Monitoring at Solid Waste Disposal Facilities," EPA-530/SW-611, August 1977, for sample collection, sample preservation and shipment, analytical procedures, and chain of custody control. This specification provides guidance while at the same time allowing the originally intended latitude in those cases where several methods may be acceptable. The final interim status regulation now requires the facility owner or operator to develop and follow a ground-water sampling and analysis plan which must include procedures and techniques for sample collection, sample preservation and shipment, analytical procedures, and chain of custody control. This plan must be kept at the facility so it will be available for inspection by the Regional Administrator or facility inspector.

List of Parameters. The proposed parameters listed for analysis received considerable attention during the comment period. Several alternatives were recommended, including suggested additions and deletions to the list, tailoring the list to the facility wastes, and using a variable list in which subsequent analyses are based on previous results. Many commenters believed that there is no need to

analyze for substances which are not supposed to be handled at the facility. One commenter felt that the abbreviated list was inadequate to detect the migration of hazardous waste and that the annual sampling and analysis frequency was insufficient. Another stated that the comprehensive list should be periodically lengthened to include new constituents from the waste manifest. Many commenters objected to the number and expense of the proposed parameters on the comprehensive analysis list. Commenters also pointed out that the large number of comparisons required in the proposal would cause a high probability of detecting significant differences when no real ground-water quality change had occurred (false significance). For further details, see the discussion of statistical methods in the section on preparation, evaluation and response.

The Agency believes that the disadvantages of most of the suggested alternative schemes outweigh their merit. It was frequently suggested that the list of characteristics for comprehensive analyses contain only those substances or characteristics which were the cause of the wastes being labeled hazardous. However, rather than limiting the numbers of analyses to anticipated waste constituents, the Agency has chosen to limit the analyses to parameters in Appendix III reflecting the aquifer's suitability as a drinking water supply (analyzed quarterly for first year only); six parameters which are commonly used to characterize ground-water quality (analyzed annually); and four indicator parameters used to determine

if a facility is leaking (analyzed semi-annually). While limiting the routine analyses to the anticipated constituents may have merit in a few cases, in general the Agency feels that this approach is not prudent. In specifying parameters which are indicators of the broad range of anticipated constituents, the Agency believes that the need to analyze for specific waste constituents may be deferred until facility leakage to the ground water has been detected. Since the owner or operator will seldom if ever be advised of all the toxic components of a particular waste and since it would not be feasible to make this determination on a load-by-load basis, many of the toxic substances not on the manifest would go undetected. Even if all of the toxic components were inventoried, many would still go undetected because of the likely possibility that many of the waste components could be chemically or biologically transformed into other toxic substances. A great many facilities may be used for a wide variety of wastes. The Agency takes the position that many owners or operators will have no way of estimating what environmental or health damage could result from discharge of leachate from the nonhazardous portion of wastes. A program to routinely determine the absence of particular contaminants from each shipment of wastes would be prohibitively expensive, yet faulty assumptions about waste content or decomposition products could result in widespread undetected contamination. In the event that a ground-water quality assessment is required, the owner or operator will need to determine the

presence of and concentration of hazardous waste and hazardous waste constituents in the ground water. The Agency believes that techniques such as gas chromatography will be used to determine which hazardous waste constituents are in the ground water.

As previously discussed, the Agency proposed monitoring regulations designed to assure detection of unacceptable performance under a standard prohibiting "endangerment." Many commenters suggested that a list of 10 or fewer indicators be selected for routine analysis representing broad classes of contaminants which may be present in the waste and capable of endangering ground water. Others suggested that the minimum list of analyses serve as a guide to make a more comprehensive investigation when the levels established in background analyses are exceeded. Two commenters suggested ways of allowing the Regional Administrator to shorten the list when appropriate, either by substituting a Regional Administrator-approved list where equivalent protection could be demonstrated, and/or by allowing the Regional Administrator to delete specified parameters at facilities where there is clearly no possibility of their occurrence, such as certain on-site facilities. These concerns are largely satisfied in the final regulation, where the objective of routine monitoring is now the detection of leakage into ground water using indicator parameters, not the identification of specific harmful emitted constituents. Since monitoring does not have to result in a determination regarding endangerment, the parameters listed for monitoring no longer need to be associated with "increased treatment" requirements.

With this monitoring objective in mind, primary consideration was given to selecting those parameters which would most likely indicate leachate movement at the widest variety of sites, be generally accepted by the scientific community as those which would be most representative of ground-water quality, and be readily quantifiable.

Specific comments pertaining to the proposed comprehensive analysis list are noted below:

- Several commenters noted the redundancy of total dissolved solids, specific conductivity, chloride, and other characteristics. The Agency agrees and has deleted redundancies from the final revised regulations.

- Dissolved organic carbon, BOD, COD, and other gross organic indicators were attacked by reviewers as being insufficiently sensitive to detect some highly toxic organics which are dangerous at very low levels. The Agency agrees that these indicators should not be used specifically to detect such contaminants. Their use will be restricted to indicate the presence of gross organic emissions as part of a set of indicators that discharge has occurred. Low level toxics will be investigated only after determination that ground water has been contaminated (see discussion of ground-water quality assessment below).

- Several commenters suggested that there are procedural reasons that the list of contaminants contained in the National Secondary Drinking Water Regulations should not be used. Whether the contaminants have regulatory status in another EPA program should not affect their use in these regulations. The Agency feels that each characteristic should be evaluated on its individual merits, and points out that no arguments were presented during the comment period that any of the characteristics in that list would be inappropriate for determining a facility discharge. The argument that the secondary contaminant levels are not enforceable, or that they are suggestions which the states may revise or disregard, does not apply to a discussion of the lists of analyses. The recommended numerical limit is immaterial for routine monitoring, under the final regulations. The list of parameters should comprise useful characteristics which indicate whether or not the facility is

in compliance with regulations, the list's origin and other uses notwithstanding.

- The Agency agrees with the commenter who suggested that ground-water quality standards should not be adopted from the proposed or final editions of the Water Quality Criteria, published in accordance with Section 304(a) of the C.W.A. (33 U.S.C. 131f(a)) without formally proposing them for application in these regulations.

- The Agency agrees with the comment that the phrase "principal hazardous constituents" is vague. It has been deleted from the monitoring requirements in these regulations.

- Upon obtaining consecutive analytical results showing the absence or very low concentrations of a particular background characteristic, some commenters recommended deleting that characteristic from subsequent analyses for background determinations. In view of the importance of establishing representative background water quality data on a continuing basis, the Agency takes the position that background values will probably be variable and, therefore, it would be inappropriate to delete a particular characteristic based on the historical absence of it. Determination of background water quality is in the operator's best interest in order to demonstrate whenever water quality degradation has been caused by other sources. Therefore, the Agency is requiring continued determinations even of those characteristics which initially were absent.

- The comment was made that water level should be recorded with each sample. The Agency agrees that the water table gradient is indeed essential information without which system integrity cannot be assured. Sampling and analysis requirements have been revised to require water level monitoring to detect shifts in water table gradient.

- Gas chromatographic scans were roundly criticized as being too nonspecific for regulatory purposes, too expensive, too easy to distort the conclusions for some waste types, and too sophisticated and time consuming. No commenters favored regular use of gas chromatography. The Agency agrees and will not require the test on a routine basis. However, when a ground-water quality assessment is required or when an owner or operator chooses to implement an alternative monitoring system rather than indicator monitoring, methods such as gas chromatography/mass spectrometry (GC/MS) would be needed to successfully identify specific hazardous wastes and hazardous waste constituents.

Rationale for Chosen Action

As a result of the many comments received on this topic the Agency has thoroughly reevaluated various sampling and analysis protocols for effective ground-water monitoring. This reevalution has convinced the Agency that various sampling and analysis requirements for several different objectives are appropriate. These final regulations include a threestage approach. The first stage involves establishment of initial background ground-water quality for those parameters listed in Primary Drinking Water Regulations as well as ten other useful ground-water quality parameters and indicators of ground-water contamination. Seasonal water table gradients will also be determined. From this stage the Agency, first, will be fully aware of the initial suitability of the ground water as a drinking water supply; second, will initiate a baseline for in-depth analyses of suspected ground-water contamination if a ground-water quality assessment is required; and third, will establish the baseline for later comparison of routinely monitored indicator parameters. For upgradient wells, the mean and variance of each indicator parameter concentration or value must be determined by pooling of all replicate measurements for the respective parameters for all quarterly samples obtained during the first year. At least four replicate measurements must be obtained for each indicator parameter concentration or value to provide statistically valid data for future comparisons. Pooling will also account for seasonal fluctuations in the upgradient ground-water quality.

The second stage, following establishment of initial background water quality, involves routine water quality measurement, discharge detection, and water table gradient monitoring. Facilities not impacting ground water will continue this stage throughout the monitoring period. If the results of analyses in this stage indicate that the facility is impacting ground water, the owner or operator is required to implement a thorough ground-water quality assessment, the third stage.

Procedures for sampling and analysis. The facility owner or operator is required to develop and follow a sampling and analysis plan which must be kept at the facility. Techniques for sample collection, preservation and shipment, and the laboratory procedures are influenced by the installed system, site-specific geology, and available laboratory capabilities, to some extent. A comment accompanies the regulation which suggests use of the procedures contained in two EPA manuals, "Procedures Manual for Monitoring at Solid Waste Disposal Facilities," EPA-530/SW-611, August 1977, and "Methods for Chemical Analysis of Water and Wastes," EPA-600/4-79-020, March 1979. Variations of these suggested procedures may also be used. Control over the chain-of-custody of the samples, analyses and data should be the responsibility of the owner or operator to assure EPA that only the owner or operator or his agents have custody.

The final interim status rule states:

§265.92 (a) The owner or operator must obtain and analyze samples from the installed ground-water monitoring system. The owner or operator must develop and follow a ground-water sampling and analysis plan. He must keep this plan at the facility. The plan must include procedures and techniques for:

(1) Sample collection;
(2) Sample preservation and shipment;
(3) Analytical procedures; and
(4) Chain of custody control.

[Comment: See "Procedures Manual For Ground-water Monitoring At Solid Waste Disposal Facilities," EPA-530/SW-611, August 1977 and "Methods for Chemical Analysis of Water and Wastes," EPA-600/4-79-020, March 1979 for discussions of sampling and analysis procedures.]

Selection of Parameters. The Agency has decided that the most effective method to determine the presence of contaminants in ground water due to leachate from of a hazardous waste management facility is to select a small number of reliable, readily quantifiable indicators of organic and inorganic contamination to be used routinely. If such indicators are found to rise significantly over established background levels, ground-water contamination may be suspected, requiring more in-depth analysis and evaluation. Use of a small number of indicators will also minimize the number of false positive determinations when the statistical test is applied to the data. For further details, see the discussion of statistical methods.

The Agency is requiring that gross indicators of both the organic and inorganic content of ground water be monitored at least semiannually. In choosing a small select group of reliable

indicators the Agency is reducing the number of analyses that must be performed on ground-water samples by the owner or operator of a facility, thus reducing his burden while maintaining assurance that any ground-water quality change resulting from a facility discharge will be readily detected.

The lists of parameters in the final regulation have been tailored for three separate ground-water monitoring objectives: characterizing initial background water quality in terms of suitability as a source of drinking water; determining general trends in localized ground-water quality beneath the site; and detecting facility discharges. Initial suitability is expressed in terms of the concentrations of the contaminants listed for ground water in the National Interim Primary Drinking Water Regulations (Appendix III). These twenty contaminants (a twenty-first contaminant, turbidity, is applicable only to surface water supplies) have been identified by the Agency as substances for which all public water supply systems in the U.S. should be routinely analyzed. Contaminant limits have been established for these substances based upon their known effects on man when consumed in drinking water. Initial determination of their levels in the ground water beneath the site is needed to fully characterize the suitability of the aquifer as a source of drinking water for human consumption.

The second list of parameters contains six selected substances which are sensitive to a wide variety of influences and ground-water

changes. The Agency believes that any ground-water quality change due to other sources of contamination or to regional influences will be reflected in the levels of these six parameters. General trends in regional ground-water quality, such as oxygen depletion, acidity or alkalinity changes, and organic and ionic enrichment, will influence these parameters. This water quality data will be collected annually so that in the event contamination is detected by the indicator parameters, comparative data will be available on which to base a more extensive ground-water quality assessment. Since there is no a priori information available as to the type or extent of background data needed, the Agency has elected to require a set of six parameters (sodium, sulfate, iron, manganese, chloride, and phenols) which it feels is representative of the data that will be needed in the event such an assessment becomes necessary. In selecting these parameters, primary consideration was given to those water quality criteria that are routinely used in characterizing drinking water and water for other purposes.[9,13,37,52,65] The Agency expects that if a ground-water quality assessment is ever required, these six parameters will not, by themselves, be adequate to establish a basis for an in-depth comparison but rather will form a nucleus of a more extensive set of background data to be determined if such a situation arises. By virtue of their widespread use and generally accepted value as water quality parameters the procedures for analysis have been standardized[11] and thoroughly tested.[57]

There is no provision in the present regulations for dealing with specific wastes on a case-by-case basis, and even if there were, so little is known in regard to the transport and ultimate fate in the subsurface of the types of compounds that will result from hazardous waste, it would be of little value in predicting precisely which parameters should be monitored. This being the case, the Agency must devise a monitoring protocol that will be responsive to a large, undefined set of chemical compounds at unspecified concentration levels which can only be classed in general terms as ionic, non-ionic, organic, inorganic, or suspended in the ground water. An appropriate monitoring scheme must, therefore, measure and be indicative of those general properties associated with leachate contamination. Within these constraints and those set out by Gage[20] for acceptable test procedures, the Agency has chosen pH, specific conductance, total organic carbon (TOC), and total organic halogen (TOX) to be used as indicators of leachate contamination of ground water and will be determined at least semiannually. Statistically significant changes in these parameters over established background levels will trigger the requirement for more detailed analysis and evaluation.

Specific conductance, pH and TOC are widely used by both researchers in the field and various regulatory agencies and are considered to be among the most useful in detecting leachate contamination in a wide variety of situations.[11,62,64,68] Like the

ground-water quality parameters discussed earlier, methods for these three indicators have been standardized and thoroughly tested.[57] Use of TOX as an indicator is gaining increasing acceptance as demonstrated by its use by several universities and government agencies.[27] Standardization of TOX procedures is being conducted by a committee of the American Society of Testing and Materials (ASTM) for inclusion in the Annual Book of ASTM Standards.[16] Expanded use of the TOX procedure is expected as the accessibility to users of existing instrumentation is increased.

The Agency is aware of another method of determining organic halogen content in water samples (i.e., gas chromatography/mass spectrometry (GC/MS)). GC/MS can yield an additive value for organic halogen content of a sample through summing the concentrations of individually identified organic halogens. Compared to the TOX analysis required in these regulations, the GC/MS procedure is more complex to perform, is more expensive with respect to cost of the instrumentation and is unable to readily serve the function of an "indicator."

The monitoring protocol of the final regulation effectively reduces the number of analyses compared to that required in the proposed regulation but at the same time maintains a high degree of assurance that changes in ground-water quality due to leachate contamination will readily be detected.

It has been recently pointed out that an acceptable test procedure must possess many different qualities.[20] Important among these are that it must be generally accepted by the scientific community as indicative of the particular characteristic to be measured; must be thoroughly tested and evaluated; and it must give precise and accurate results. Other qualities include: the capability of measuring the parameter in the presence of interferences; relative simplicity, so as to minimize time requirements; the availability of necessary instrumentation on the open market at a reasonable cost; the utilization of standard laboratory methods; and finally that there be sufficient analysts available having the necessary skills and training to carry out the test procedure. These factors and others formed the basis for selecting both the water quality parameters and the contamination indicators contained in the final regulations.

Specific conductance and pH were chosen for monitoring the inorganic constituents because they satisfy virtually every requirement for being acceptable test procedures, and there are no alternative inorganic indicators which can provide equivalent informational value. Aside from its importance as an absolute measure of hydrogen ion activity, pH is valuable as an indicator to detect if a particular water is being altered by other waters with a different pH. pH affects the solubility and mobility of many of the toxic constituents of wastes, and it determines the rate and outcome of many of the chemical reactions the pollutants will undergo. Specific conductance

on the other hand is a numerical expression of the summation of contributions from all ions present in a solution. Since conductance is an additive property, it is useful as an indicator parameter because it can effectively determine all ions simultaneously. It has successfully been used to check for the presence or absence of leachate in ground-water and also to detect fluctuations and trends of the total ionic properties of groundwater.[2,3,4,5,6,7,61,66]

While pH and specific conductance are somewhat redundant and while a change in pH is generally accompanied by a change in specific conductance, or vice versa, this is not always the case. At least one EPA report shows unexplained changes in one without a corresponding change in the other.[66]

TOC was chosen as an indicator parameter for organics because of its widespread use, acceptability as an effective test procedure, and general applicability to all types of organic contamination.[11,61,62,68] It is one of the few parameters that will provide a broad description of the organic content of water and is gradually replacing chemical oxygen demand (COD) for this purpose, especially in ground-water analysis. TOC provides a more direct expression of organic content than COD, is more sensitive, and is a less difficult procedure.

TOX was selected to measure only those organic compounds containing halogens. It has been used successfully in recent years and its use is expanding in this country, Canada, and

Europe.[17,21,25,26,32,45,46,71] Despite the somewhat more limited use of TOX, the Agency feels that in view of the relatively large amount of hazardous waste which may contain halogenated hydrocarbons and the higher degree of toxicity usually associated with these compounds, it should be included as an indicator. The TOC test alone will not reliably detect the minor TOC fluctuations due to significant levels of halogenated hydrocarbons, and the TOX test alone will not provide the broad range of organic coverage necessary.

Gas chromatography (GC) was originally part of the comprehensive analysis list in the proposed regulations. Its use in the final regulation was seriously considered in spite of the several serious disadvantages which were identified by commenters. Neither GCM or GC/MS is readily adaptable as an indicator. Several commenters correctly noted that GC would probably be too confusing to be used as an indicator parameter. On the other hand, GC/MS would enjoy the distinct advantage of providing a unique means of identifying the individual components of a complex mixture of many different organic compounds. In spite of this unique advantage and its substantially higher sensitivity, GC/MS was rejected for routine analyses because it fails to meet many other requirements for being an acceptable test procedure. It requires extremely expensive instrumentation that is difficult to operate and not readily available. Including sample preparation, GC/MS requires substantial amounts of time to carry out, and there are relatively few analysts capable of running the equipment or interpreting the results.

The final interim status rule states:

§265.92(b) The owner or operator must determine the concentration or value of the following parameters in ground-water samples in accordance with paragraphs (c) and (d) of this Section:

(1) Parameters characterizing the suitability of the ground water as a drinking water supply, as specified in AppendixIII.

(2) Parameters establishing ground-water quality:

(i) Chloride
(ii) Iron
(iii) Manganese
(iv) Phenols
(v) Sodium
(vi) Sulfate

[Comment: These parameters are to be used as a basis for comparison in the event a ground-water quality assessment is required under §265.93(d).]

(3) Parameters used as indicators of ground-water contamination:

(i) pH
(ii) Specific Conductance
(iii) Total Organic Carbon
(iv) Total Organic Halogen

Monitoring Frequency. The Agency has selected a monitoring schedule for routine monitoring which is both reasonable and protective. Quarterly background sampling and analysis for the first year, annual ground-water quality determinations and semiannual contamination-indicator samples are required at all wells. The Agency believes that the required schedule is environmentally safe, prudent and readily achievable at all facilities.

APPENDIX III

EPA INTERIM PRIMARY DRINKING WATER STANDARDS[65]

Parameter	Maximum Level (mg/l)
Arsenic	0.05
Barium	1.0
Cadmium	0.01
Chromium	0.05
Flouride	1.4-2.4
Lead	0.05
Mercury	0.002
Nitrate (as N)	10
Selenium	0.01
Silver	0.05
Endrin	0.0002
Lindane	0.004
Methoxychlor	0.1
Toxaphene	0.005
2, 4-D	0.1
2, 4, 5-TP Silvex	0.01
Radium	5 pCi/l
Gross Alpha	15 pCi/l
Gross Beta	4 millirem/yr
Turbidity	1/TU
Coliform Bacteria	1/100 ml

NOTE:

Turbidity is applicable only to surface water supplies (see ref. 65).

The final interim status rule states:

§265.92(c) (1) For all monitoring wells, the owner or operator must establish initial background concentrations or values of all parameters specified in paragraph (b) of this Section. He must do this quarterly for one year.

(2) For each of the indicator parameters specified in paragraph (b)(3) of this Section, at least four replicate measurements must be obtained for each sample and the initial background arithmetic mean and variance must be determined by pooling the replicate measurements for the respective parameter concentrations or values in samples obtained from upgradient wells during the first year.

(d) After the first year, all monitoring wells must be sampled and the samples analyzed with the following frequencies:

(1) Samples collected to establish ground-water quality must be obtained and analyzed for the parameters specified in paragraph (b)(2) of this Section at least annually.

(2) Samples collected to indicate ground-water contamination must be obtained and analyzed for the parameters specified in paragraph (b)(3) of this Section at least semi-annually.

Water Table Gradient. The velocity and direction of the flow of ground water beneath a site are dependent upon both natural and man-induced influences. Nearby well extractions, surface water discharges and recharges, flood control measures and other hydrogeologic modifications, as well as natural and seasonal influences, can change the direction and velocity such that a properly installed monitoring system becomes obsolete. The final regulations require the owner or operator to determine the water surface elevation in each well quarterly for the first year and semiannually thereafter. These

elevations will be used as an indication of water table gradient and, when change is observed, the well location requirements must be reevaluated, as described in preparation, evaluation and response, below.

The final interim status rule states:

§265.92(e) Elevation of the ground-water surface at each monitoring well must be determined each time a sample is obtained.

5. Preparation, Evaluation and Response

Synopsis of Proposed Regulation

As proposed, the regulations required the owner/operator, upon observing statistically significant differences between background quality and subsequent ground-water quality analyses to: notify the Regional Administrator of the observance; determine the cause of the observance; determine the extent of ground-water contamination; and discontinue facility operations while awaiting instructions from the Regional Administrator.

Rationale for the Proposed Regulation

While selection of many of the ground-water quality parameters was based on the proposed human health and environmental standard, the emergency response was keyed to the facility standards which required that facilities be designed, constructed and operated so that discharges are minimized or do not occur. The regulatory intent was that the owner/operator and the Regional Administrator be in communication, so that there would be a common understanding of the

background water quality and the specific analytic results which constituted a significant difference, and that upon notification, the Regional Administrator would commence an immediate review of evidence at the facility and determine with the operator any necessary actions. It was expected that the contingency plan established under §250.43-3 would contain facility-specific sets of conditions upon which appropriate response would be made contingent. While these plans would be examined during the permit application and review process and cover the forseeable conditions of discharge or failure at the facility, it is conceivable that the actually occurring situation could differ from the anticipated. It was review of these differences by the Regional Administrator that the owner or operator would await after reporting the statistically significant difference pursuant to §250.43-8(c)(4).

Comments Received and Agency Response

Commenters on the proposed emergency response procedures stated that the automatic response of discontinuing operation immediately after observing a statistically significant difference was seldom likely to be warranted. They also point out that the language was not precise; it even required shutdown when upgradient wells were affected. It was made clear that the intended relationship between the emergency response and the contingency plan was not adequately developed in the proposed regulation.

Commenters recommended that the operator's response to analytical results be related to the magnitude and nature of the change in ground-water quality. Facility closure, it was indicated, should automatically result only from the most drastic indications for alarm. Normal aberrations in data should be expected, and the more appropriate response would be accelerated sampling and analysis schedules. Closure of the facility, even for a few days, could cause severe hardship to haulers and generators as well as to facility operators, often with only undetectably small environmental benefit. The Agency agrees that automatic shutdown may be unwarranted in many situations before an actual determination of the extent of the problem.

Several commenters pointed out that the proposed regulations would require the notification and shutdown procedures upon observing a statistically significant improvement in the quality of the background water. This was not the Agency intent.

Several commenters suggested that the regulations establish a time limit for the Agency's response to notification. As proposed, the facility would be shut until the Regional Administrator determined what actions should be taken. They feared that, with confusing data, indecisive officials could unduly procrastinate, delaying both a positive remedy and the resumption of operation. The Agency agrees that delays and indecision are to be avoided following observance of a water quality change.

Rationale for Chosen Action

The final regulations have been developed to facilitate a sequential response to detected changes in ground-water quality. Following detection of a statistically significant increase (or pH decrease) over background in the concentration of one of the indicator parameters at a downgradient monitoring well, this sequence will be followed:

1) verification of laboratory results

2) notification of the Regional Administrator

3) submission of a ground water quality assessment plan

4) performance of a ground water quality assessment

5) preparation and submission of an assessment report to the Regional Administrator, and

6) Continuance of ground-water quality assessments on a quarterly basis until closure (if contamination first appears during post-closure, only a single assessment need be performed).

The final regulations require the owner/operator to prepare an outline of a ground water quality assessment program to determine the extent and severity of suspected ground-water contamination. This outline is intended to serve as a basis for a comprehensive assessment plan which is to be developed and submitted to the Regional Administrator following detection of a significant increase in the concentration of an indicator parameter in a downgradient well.

The Agency recognizes that it is difficult to specify details of a comprehensive ground-water quality assessment in advance of the

event. However, the Agency believes that an outline of a program should be available at a hazardous waste management facility to guide more detailed plan development, if ever required, without delay.

The final interim status rule states:

§264.93(a) Within one year after the effective date of these regulations, the owner or operator must prepare an outline of a ground-water quality assessment program. The outline must describe a more comprehensive ground-water monitoring program (than that described in §§265.91 and 265.92) capable of determining:

(1) Whether hazardous waste or hazardous waste constituents have entered the ground water;

(2) The rate and extent of migration of hazardous waste or hazardous waste constituents in the ground water; and

(3) The concentrations of hazardous waste or hazardous waste constituents in the ground water.

The final regulations specify the procedures for determining when a statistically significant increase (or pH decrease) in the concentration of the indicator parameters in ground-water samples has occurred. The arithmetic mean and variance, based on at least four replicate measurements for each parameter, for samples from each well in the ground-water monitoring system are to be statistically compared with the initial (historic) background water quality for these parameters, using a Student's t-test. The statistical requirements in this Subpart are discussed in the next section of this document. If a significant difference is detected, one of two actions is triggered. If the significant difference is detected in an upgradient monitoring well the owner/operator is required to include a discussion of this occurrence in his annual report submission to the

Regional Administrator. If, however, a significant difference is detected in a downgradient well, the facility is immediately suspected of contaminating ground water.

If suspected, the owner/operator is required to obtain additional samples for analysis from those downgradient wells showing a statistically significant increase (or pH decrease). Each of the additional samples is to be split into two samples and submitted to the lab for analysis. This step is included in the regulations to reduce the possibility of a laboratory error causing the significant difference. Unless the owner/operator is able to demonstrate laboratory error, he must, within seven days, notify the Regional Administrator, state and local officials that his facility may be affecting ground water.

The final interim status rule states:

§265.93(b) For each indicator parameter specified in §265.92(b)(3), the owner or operator must calculate the arithmetic mean and variance, based on at least four replicate measurements on each sample, for each well monitored in accordance with §265.92(d)(2), and compare these results with its initial background arithmetic mean. The comparison must consider individually each of the wells in the monitoring system, and must use the Student's t-test at the 0.01 level of significance (see Appendix IV) to determine statistically significant increases (and decreases, in the case of pH) over initial background.

(c) (1) If the comparisons for the <u>upgradient</u> wells made under paragraph (b) of this Section show a significant increase (or pH decrease), the owner or operator must submit this information in accordance with §265.94(a)(2)(ii).

(2) If the comparisons for downgradient wells made under paragraph (b) of this Section show a significant increase (or pH decrease), the owner or operator must then immediately obtain additional ground-water samples from those downgradient wells where a significant difference was detected, split the samples in two, and obtain analyses of all additional samples to determine whether the significant difference was a result of laboratory error.

In the event that an owner/operator is required to notify the Regional Administrator concerning possible ground-water contamination, the regulations allow a two week period during which he must develop a detailed plan for performance of a ground-water quality assessment, based upon the previously prepared ground-water quality assessment program outline, and submit it to the Regional Administrator. The regulations indicate that the plan must specify well number, location and depths, and sampling, analysis and evaluation procedures to be used to determine the cause, extent and severity of ground-water contamination and a schedule for implementing the plan. While not specifically required in the regulations the Agency anticipates that an assessment plan will incorporate comprehensive analytical techniques, such as gas chromatography/mass spectrometry, in order to accomplish a thorough assessment; such techniques will be necessary to determine the rate and extent of migration, as well as the concentration, of hazardous waste constituents in the ground water.

The regulations also incorporate a provision for the owner/operator to submit information obtained from previous facility

ground-water monitoring activities which demonstrate that the detected significant differences in the indicator parameters were not caused by the facility. EPA anticipates that the data collected on the ground-water quality parameters (i.e., chloride, iron, manganese, phenols, sodium and sulfate) will be used for this purpose.

The final interim status rule states:

§265.93(d) (1) If the analyses performed under paragraph (c)(2) of this Section confirm the significant increase (or pH decrease), the owner or operator must provide written notice to the Regional Administrator--within seven days of the date of such confirmation--that the facility may be affecting ground water quality.

(2) Within 15 days after the notification under paragraph (d)(1) of this Section, the owner or operator must develop and submit to the Regional Administrator a specific plan, based on the outline required under paragraph (a) of this Section and certified by a qualified geologist or geotechnical engineer, for a ground-water quality assessment program at the facility.

(3) The plan to be submitted under §265.90(d)(1) or paragraph (d)(2) of this Section must specify:

(i) The number, location, and depth of wells;

(ii) Sampling and analytical methods for those hazardous wastes or hazardous waste constituents in the facility;

(iii) Evaluation procedures, including any use of previously-gathered ground-water quality information; and

(iv) A schedule of implementation.

After submitting the plan to the Regional Administrator the owner or operator must implement the plan. In order to evaluate the potential danger, the plan must determine at a minimum the rate and

extent of migration of the hazardous waste constituents in the ground water. In addition, it must determine what concentrations of these constituents are present in the ground water. The initial assessment must be performed as quickly as is technically feasible. The entry of hazardous waste constituents into ground water may be presenting a serious health risk. It is therefore important that the assessment be initiated quickly once contamination is discovered. The owner or operator must submit a written report to the Regional Administrator, within fifteen days after completing the determination, containing the results of the assessment.

Depending upon the results of the assessment, the indicator evaluation program may be reinstated if it is demonstrated that no hazardous waste or hazardous waste constituents from the facility have entered ground water. However, if ground water has been impacted the owner or operator is required to continue the assessment on a quarterly basis until closure. If the determination that ground water is impacted occurs during the post-closure period the assessment program may cease.

The rationale for the above-stated process is described in the preamble. The main reason for increasing the assessment to quarterly during the active life is to allow the Regional Administrator to evaluate more frequent analyses of the contamination problem once it has occurred.

During the post-closure period it is assumed that adequate closure procedures have been carried out, that surface drainage has been diverted, cover material installed and the amount of leachate production significantly reduced. Moreover, no additional waste is being applied to the facility. With these controls in place, the amount of ground-water contamination can be expected to reduce, if not cease. Because of this the Agency felt that a single ground-water quality assessment during post closure would be adequate. It should be kept in mind that monitoring of the indicator parameters will continue through post closure until contaminants are detected and the problem is assessed.

Within seven days of shifting from an indicator evaluation program to a ground-water quality assessment program, the owner or operator must notify the Regional Administrator. A similar notice must be given when the owner or operator shifts back to an indicator program after conducting a ground-water quality assessment program. These provisions assure that the Regional Administrator will know which program the owner or operator is implementing. In setting priorities for permitting it will be particularly important to know which set of facilities are introducing hazardous waste constituents into ground water.

The final interim status rule states:

§263.93(d) (4) The owner or operator must implement the ground-water quality assessment plan which satisfies the requirements of paragraph (d)(3) of this Section, and, at a minimum, determine:

(i) The rate and extent of migration of the hazardous waste or hazardous waste constituents in the ground water; and

(ii) The concentrations of the hazardous waste or hazardous waste constituents in the ground water.

(5) The owner or operator must make his first determination under paragraph (d)(4) of this Section as soon as technically feasible, and, within 15 days after that determination, submit to the Regional Administrator a written report containing an assessment of the ground-water quality.

(6) If the owner or operator determines, based on the results of the first determination under paragraph (d)(4) of this Section, that no hazardous waste or hazardous waste constituents from the facility have entered the ground water, then he may reinstate the indicator evaluation program described in §265.92 and paragraph (b) of this Section. If the owner or operator reinstates the indicator evaluation program, he must so notify the Regional Administrator in the report submitted under paragraph (d)(5) of this section.

(7) If the owner or operator determines, based on the first determination under paragraph (d)(4) of this Section, that hazardous waste or hazardous waste constituents from the facility have entered the ground water, then he:

(i) Must continue to make the determinations required under paragraph (d)(4) of this Section on a quarterly basis until final closure of the facility, if the ground-water quality assessment plan was implemented prior to final closure of the facility; or

(ii) May cease to make the determinations required under paragraph (d)(4) of this Section, if the ground-water quality assessment plan was implemented during the post-closure care period.

(e) Notwithstanding any other provision of this Subpart, any ground-water quality assessment to satisfy the requirements of §265.93(d)(4) which is initiated prior to final closure of the facility must be completed and reported in accordance with §265.93(d)(5).

The final regulations now include a requirement that the facility owner/operator, at least annually, evaluate the water table elevation data which is to be gathered for each ground-water sampling interval. This water level data will be used to calculate the direction of ground-water flow to determine whether or not his downgradient wells are still downgradient, as required in §265.91(a)(2), such that these wells will continue to detect discharges from the waste management area. If this evaluation shows that the direction of ground-water flow has appreciably changed, the owner/operator must modify his ground-water monitoring system accordingly.

The final interim status rule states:

§265.93(f) Unless the ground water is monitored to satisfy the requirements of §265.93(d)(4), at least annually the owner or operator must evaluate the data on ground-water surface elevations obtained under §265.92(e) to determine whether the requirements under §265.91(a) for locating the monitoring wells continues to be satisfied. If the evaluation shows that §265.91(a) is no longer satisfied, the owner or operator must immediately modify the number, location, or depth of the monitoring wells to bring the ground-water monitoring system into compliance with this requirement.

6. Statistical Methods (Appendix IV)

Synopsis of Proposed Regulations

The proposed regulation required that the results of sampling and analysis of ground-water monitoring wells be statistically compared to established background ground-water quality using the

Student's t, single-tailed test at the 5 percent level of significance. As a result of the analysis of comments received, the Agency re-proposed the statistical test for ground-water monitoring data evaluation. On September 19, 1979, the Agency proposed the use of the Mann-Whitney U-test at the 5 percent level of significance.

Rationale for the Proposed Regulations

The Agency's initial selection of the Student's t-test was an attempt to require use of a familiar statistical testing procedure which was generally well suited for evaluation of ground-water monitoring data. The Agency's reproposal of the Mann-Whitney U-test was an attempt to overcome the suggested major weakness of the Student's t-test, namely its underlying assumption of "normality."

Comments Received and Agency Response

Comments received can be classified into four groups: statistical model and the underlying assumptions; type I ( ) error rate resulting from multiple comparisons; spacial and temporal variations in ground-water quality; and the number of replicate measurements to be taken on each monitoring sample of ground water.

Statistical model and the underlying assumptions: The majority of commenters felt that the Student's t-test was the better test even though there is some question regarding the assumption of normality. The Student's t-test assumes that both sets of samples (i.e., initial background and periodic) are random samples drawn from normal populations with equal variances. Numerous studies have shown

that the t-test is robust (i.e., tolerant) to considerable departures from underlying assumptions.[8] The Agency has reconsidered use of the Student's t-test in light of the comments received.

Type I (α) error rate resulting from multiple comparisons: Many commenters were concerned about the compounding of type I error (detection of false significance) due to multiple comparisons of several variables between the upgradient and downgradient wells. The Agency recognizes that this is a serious concern and has incorporated changes in the methodology to control for this compounding (see next section).

Spacial and temporal variation in ground-water quality: Commenters were concerned that the proposed method of comparing samples, without considering variations related to time and space, would result in the detection of significant difference attributable to natural variability in ground-water quality and not to facility contributions to ground water. The Agency agrees that these concerns are valid and has modified the proposed methodology to incorporate estimates of these components of variability by establishment of background data for a period of one year prior to actual "compliance" monitoring.

The number of replicate measurements to be taken on each ground-water sample: Several commenters were concerned about the number of replicates to be obtained on each sample. While the number of replicates was not specified in the originally proposed regulations,

seven replicate measurements were suggested as providing a minimum level of power for the Mann-Whitney U-test. In response to comments, however, the final required methodology establishes a minimum number of replicates based upon a more appropriate approach.

Rationale for Chosen Action

Based on the comments received, the Agency is again specifying the use of the Student's t-test to detect leaching of hazardous waste or hazardous waste constituents into the ground water.

The Student's t-test is intended to detect differences in the sample mean values between periodic and initial background indicator parameter concentrations or values. As indicated, the Student's t-test is robust (i.e., relatively insensitive) to the underlying assumption of normality and therefore can be successfully used in situations where the underlying distribution deviates from normality.[8] The methodology required in these final regulations involves comparison of periodically determined concentrations of four indicator parameters with their initial background concentrations. The initial background concentrations are established by quarterly sampling and analysis of the upgradient well for a period of one year. Initial background, therefore, incorporates both measurement error and usual fluctuations of ground-water quality over time into the estimates of means and variance used in the statistical testing.

The Student's t-test involves the calculation of a t-statistic, using sample means and variances of measurements on the indicator

parameters. The t-test allows the comparisons to the background means. Critical values for the t-statistic at a given level of significance can be found in most introductory statistics texts.[15]

The t-statistic is calculated as follows:[69]

$$t = \frac{\bar{x}_p - \bar{x}_b}{S_t \sqrt{(1/n_p) + (1/n_b)}}$$

where:

$$S_t^2 = \frac{(n_p - 1)S_p^2 + (n_b - 1)S_b^2}{n_p + n_b - 2}$$

and where: t = the calculated t-statistic with k degrees of freedom; $k=n_p+n_b-2$.

$\bar{x}_p$ = the calculated arithmetic mean of the replicate measurements for a single indicator parameter for a given periodic sampling event.

$\bar{x}_b$ = the calculated arithmetic mean of all the replicate measurements for single indicator parameter obtained during establishment of initial background.

S^2_p = the calculated variance of the replicate measurements for a single indicator parameter for a given periodic sampling event.

S^2_b = the calculated variance of all the replicate measurements for a single indicator parameter obtained during establishment of initial background.

n_p = the numbers of replicate measurements for a single indicator parameter for a given periodic sampling event (no fewer than four replicates).

n_b = the total number of replicate measurements for a single indicator parameter obtained during establishment of initial background (no fewer than 16 replicates).

For three of the four indicator parameters (specific conductance, total organic carbon, and total organic halogen) only increases over initial background levels are of interest; therefore, for these indicators single-tailed tests are to be made at the 0.01 level of significance. For the remaining indicator, pH, increases or decreases over background are of interest; therefore, a two-tailed test at the overall 0.01 level of significance is required.

These final regulations specify a minimum number of replicate analyses for each sample to ensure the use of accurate data in the statistical comparisons. Typical analytical apparatus and techniques can achieve an estimate of the actual concentration or value of the indicator parameters in ground-water samples that is within 5% of the actual concentration or value. That is to say, typical analytical procedures and care can achieve relative accuracy of 5% or better.[1,27,57]

Similarly, the literature indicates that typical apparatus and techniques used for analysis of the concentration or value of the indicator parameters can achieve relative precision of 5% or better (as low as 1%).[1,27,57]

In light of these capabilities for accuracy and precision the Agency determined that the 95% confidence level should be specified because it provides a high degree of assurance that the mean of the sample replicates is within ± 5% of the value being estimated. That is, if the measurement process was repeated a large number of times, roughly 95% of the means of the replicates would be within ± 5% of the actual mean value.

Under the usual assumption that measurement or laboratory error is normally distributed, the number of replicate measurements (sample size) is related to the error (the difference between the estimate and the actual quantity it is supposed to estimate) and the standard deviation of the measurement process in the following manner:[1,69]

$$N = \left(\frac{s\ z}{e}\right)^2$$

where: N = number of replicate measurement,

z = the standard normal deviate,

s = the standard deviation of the measurement process, and

e = the error in estimating the actual value.

Then, since: (1) relative precision is equal to the standard deviation divided by the actual value, and

(2) relative accuracy is equal to the error divided by the actual value,

the equation for estimating N can be rewritten as:

$$N = \frac{(\text{relative precision})^2\ (\text{standard normal deviate})^2}{(\text{relative accuracy})^2}$$

where: N = minimum number of replicate measurements

Using a value of 2 for the standard normal deviate to correspond to an approximate 95% confidence level (the exact value is 1.96), the relationship, in this case, is:

$$N = \frac{(0.05)^2\ (2)^2}{(0.05)^2} = 4$$

A minimum of four replicate measurements is, therefore, required for each indicator analysis of a ground-water sample.

In order to control for compounding of type I error due to multiple comparisons the Agency examined several univariate (e.g., Student's t vs. Mann-Whitney, sign test ANOVA, etc.) and multivariate techniques (Hotelling's T, multivariate ANOVA, etc.) and concluded that the Student's t-test provided the best overall solution given the large variability in owner or operator statistical expertise and computing capabilities. This method allows for direct paired comparisons using the Student's t-test; however, recognizing the compounding effect of multiple comparisons: the number of parameters to be compared has been reduced to four; tests for significant difference are set at the 0.01 level of significance; and, significant differences are to be confirmed by additional analysis of split samples before initiating a potentially costly ground water quality assessment.

APPENDIX IV

TESTS FOR SIGNIFICANCE

As required in §265.93(b) the owner or operator must use the Student's t-test to determine statistically significant changes in the concentration or value of an indicator parameter in periodic ground-water samples when compared to the initial background concentration or value of that indicator parameter. The comparison must consider individually each of the wells in the monitoring system. For three of the indicator parameters (specific conductance, total organic carbon, and total organic halogen) a single-tailed Student's t-test must be used to test at the 0.01 level of significance for significant increases over background. The difference test for pH must be a two-tailed Student's t-test at the overall 0.01 level of significance.

The Student's t-test involves calculation of the value of a t-statistic for each comparison of the mean (average) concentration or value (based on a minimum of four replicate measurements) of an indicator parameter with its initial background concentration or value. The calculated value of the t-statistic must then be compared to the value of the t-statistic found in a table for t-test of significance at the specified level of significance. A calculated value of t which exceeds the value of t found in the table indicates a statistically significant change in the concentration or value of the indicator parameter.

Formulae for calculation of the t-statistic and tables for t-test of significance can be found in most introductory statistics texts.

7. Recordkeeping and Reporting

Synopsis of Proposed Regulation

The proposed regulation required that the owner or operator of a facility report on a quarterly basis the results of sampling and analysis of the ground-water and leachate monitoring systems. Records of "monitoring and analytical activities and data, including all original strip chart recordings and instrumentation, calibration, and maintenance records;" were to be maintained by the owner or operator for at least three years.

Rationale for the Proposed Regulation

The general rationale for requiring the owner or operator of a facility to maintain records of the ground-water monitoring system and to periodically report such information to the Regional Administrator was to enable the Agency to have an opportunity to review the performance of a facility whether or not an indication of ground-water contamination had been reported. By specifying quarterly reporting the Agency would obtain this ground-water monitoring information within three months of sampling and analysis regardless of the frequency of sampling and analysis. In this way there would be minimal time lapse before the Agency would become aware of any unreported increase in contaminants in ground water. By requiring that records

of such monitoring be retained for a period of three years or more, the Agency would be afforded the opportunity of reviewing virtually all information and data related to the monitoring system during routine inspections or if the need arose following interpretation of monitoring data.

Comments Received and Agency Response

Reporting frequency. Very few comments were received which addressed the recordkeeping and reporting requirements of the ground-water monitoring section. No comments addressed the recordkeeping requirements of the section and nearly all comments on reporting requirements urged a reduced frequency. Since the proposed regulations permitted sampling and analysis of the monitoring system as infrequently as annually, under some circumstances, commenters stated that semiannual or annual reporting should be sufficient and permissible especially in light of the fact that within seven days of detecting a significant increase of a contaminant over established background levels the Regional Administrator was to be notified.

The Agency agrees that quarterly reporting of the ground-water monitoring system data should not be required for routine monitoring. For owners or operators performing an indicator monitoring program, annual reporting supplemented by notification within seven days of the confirmation of significant differences in indicator parameter concentrations should be sufficient to keep the Agency informed on facility performance. The Agency does, however, require quarterly

reporting of the concentrations of those parameters which characterize the suitability of the ground water as a drinking water supply, which are listed in Appendix III in the section on sampling and analysis, during the initial year when background water quality is being established. In addition, the owner or operator must identify in these quarterly reports any such primary drinking water parameter which is detected in the ground water at a concentration higher than the maximum contaminant level (MCL) for that parameter. By way of this requirement the Regional Administrator will promptly become aware of any contaminated ground-water conditions during that year which may necessitate Agency notification of nearby users of the ground water as a drinking water source. This requirement is especially important for existing facilities where ground water may have become contaminated as a result of previous waste management or other practices.

For facility owners or operators performing a ground-water quality assessment monitoring program, records of all analyses and evaluations specified in the ground-water quality assessment plan must be kept and submitted annually in a report to the Regional Administrator.

Report distribution. One commenter, who agreed with the quarterly reporting requirement, suggested that reports be provided not only to the Regional Administrator but also to both state and local authorities. The Agency believes that such distribution might

constitute an unnecessary burden on the owner or operator and on the state and local authorities who must process and review such data. Review by three or more agencies would be needlessly duplicative. Those State and local authorities that are interested in examining the reports may obtain copies from EPA or the authorized State agencies responsible for receiving such information.

Rationale for the Chosen Action

Although no comments on recordkeeping requirements were received, the Agency has included requirements in the final regulations which differ from the proposed. Whereas the proposed regulations required that records of ground-water quality be maintained for a minimum of three years, these final regulations require that ground-water quality information be maintained throughout the active life of the facility and, for disposal facilities, throughout the post-closure care period as well. Since ground-water changes may occur slowly, it will be useful to have a history of the facility that is longer than three years. This information will be invaluable in determining the significance of increases or decreases in indicator parameters and for successful completion of a ground-water quality assessment program. The proposed requirement that the records include original strip charts and other analytic information has been deleted. These final regulations only require that water quality data and appropriate evaluations for each monitoring well be maintained. (For

recordkeeping and reporting requirements for land treatment facilities, see the background document for Subpart M, Land Treatment.)

For an indicator monitoring program, with the exception of notification within seven days of significant changes in the concentration of any indicator parameter from background water quality, the Agency requires submission of ground-water quality data and evaluations only annually along with the annual report for the facility. During the first year, however, when background quality is being established, monitoring information for those parameters which characterize the suitability of the ground water as a drinking water supply must be reported quarterly. This information will be useful in identifying those aquifers which are in greatest jeopardy and to set priorities for consideration of permits. In keeping with this goal, the owner or operator must indicate in his report any such parameter which exceeds its MCL.

If a facility owner or operator initially chooses to implement a ground-water quality assessment program rather than the indicator monitoring program, or when the results of an indicator program require the owner or operator to perform a ground-water quality assessment, the recordkeeping and reporting requirements are slightly different. For a ground-water quality assessment program, the owner or operator must keep records of all analyses and evaluations specified in his ground-water quality assessment plan and submit an initial assessment as soon as is technically feasible. Thereafter annual reporting of the quarterly assessments is required.

The final regulations for indicator monitoring programs have a requirement that water surface elevations be measured and recorded during sample collection to determine changes in water table gradient (velocity or direction). The recordkeeping and reporting section in the final regulation now provides that records of gradient evaluations be submitted in the annual report along with a description of the response to such evaluations, where applicable.

The final interim status rule states:

§265.94(a) Unless the ground water is monitored to satisfy the requirements of §265.93(d)(4), the owner or operator must:

(1) Keep records of the analyses required in §265.92(c) and (d), the associated ground-water surface elevations required in §265.92(e), and the evaluations required in §265.93(b) throughout the active life of the facility, and, for disposal facilities, throughout the post-closure care period as well; and

(2) Report the following ground-water monitoring information to the Regional Administrator:

(i) During the first year when initial background concentrations are being established for the facility: concentrations or values of the parameters listed in §265.92(b)(1) for each ground-water monitoring well within 15 days after completing each quarterly analysis. The owner or operator must separately identify for each monitoring well any parameters whose concentration or value has been found to exceed the maximum contaminant levels listed in Appendix III.

(ii) Annually: concentrations or values of the parameters listed in §265.92(b)(3) for each ground-water monitoring well, along with the required evaluations for these parameters under §265.93(b). The owner or operator must

separately identify any significant differences from initial background found in the upgradient wells, in accordance with §265.93(c)(1). During the active life of the facility, this information must be submitted as part of the annual report required under §265.75.

(iii) As a part of the annual report required under §265.75: results of the evaluation of ground-water surface elevations under §265.93(f), and a description of the response to that evaluation, where applicable.

(b) If the ground water is monitored to satisfy the requirements of §265.93(d)(4), the owner or operator must:

(1) Keep records of the analyses and evaluations specified in the plan, which satisfies the requirements of §265.93(d)(3), throughout the active life of the facility, and, for disposal facilities, throughout the post-closure care period as well; and

(2) Annually, until final closure of the facility, submit to the Regional Administrator a report containing the results of his ground-water quality assessment program which includes, but is not limited to, the calculated (or measured) rate of migration of hazardous waste or hazardous waste constituents in the ground water during the reporting period. This report must be submitted as part of the annual report required under §265.75.

REFERENCES

1. Annual Book of ASTM. 1976. Part 31, Water, Standard D1125-77 through D 2579.

2. A.W. Martin Associates, Inc. 1975. Evaluation of the effect of the Lafayette, Louisiana Sanitary Landfill on ground and surface water resources. EPA contract No. 68-01-3135. 55 pages.

3. A.W. Martin Associates, Inc. 1975. Evaluation of the effect of the Lexington Co., South Carolina Landfill on ground and surface water resources. EPA contract No. 68-01-2993. 59 pages.

4. A.W. Martin Associates Inc. 1975. Evaluation of the effect of the Yates County, New York Landfill #1 on ground and surface water. EPA contract No. 68-01-2993. 55 pages.

5. A.W. Martin Associates, Inc. 1975. Evaluation of the City of Cheyenne, Wyoming Landfill on ground and surface water resources. EPA contract No. 68-01-3135. 47 pages.

6. A.W. Martin Associates, Inc. 1975. Evaluation of the effect of the Anderson Township, Ohio Fill on ground and surface water resources. EPA contract No. 68-01-3136. 51 pages.

7. A.W. Martin Associates, Inc. 1976. Evaluation of the effect of the Town of Enfield, Connecticut Sanitary Landfill on ground and surface water resources, EPA contract No. AW-464. 78 pages.

8. Boneau, C.A. 1960. "The effects of violations of assumptions underlying the t-test." Psychological Bulletin, 57:49-64.

9. Bouwer, H. 1978. Ground Water Hydrology, McGraw-Hill, New York, Chapter 10, Groundwater Quality.

10. California State Water Resources Control Board. 1978. Waste discharge requirements for nonsewerable waste disposal to land (Part E).

11. Chian, E.S.K. and F.B. DeWalle. 1975. Compilation of methodology for measuring pollution parameters of landfill leachate. U.S. Environmental Protection Agency, Cincinnati, Ohio. EPA-600/3-75-011.

12. Clark, J.P. and V.S. Gretchen. 1980. "Requirements of State regulatory agencies for monitoring ground-water quality at waste disposal sites." Ground Water, vol. 18, no. 2, pages 168-174.

13. Cox, C.R. 1964. "Operation and control of water treatment processes," Monograph Series No. 49, World Health Organization, Geneva, Switzerland. 390 pages.

14. Criteria for classification of solid waste disposal facilities and practices. FR 44 (179), September 13, 1979.

15. Dixon, W.J. and F.J. Massey. 1969. Introduction to Statistical Analysis. McGraw-Hill, New York. pages 270-273.

16. Dressman, Ronald (MERL, EPA, Cincinnati). Personal telephone communication. Subject: "TOX standardization status."

17. Dressman, R.C.; Najar, B.A. and Redzikowski, R. (Drinking Water Research Division, U.S. E.P.A., Cincinnati, Ohio 45268). Undated. "The Analysis of organohalides (OX) in water as a group parameter."

18. Fenn, D.; et al. 1977. Procedures manual for ground water monitoring at solid waste disposal facilities. EPA/530/SW-611. 269 pages.

19. Fenn, Dennis G., Keith J. Hanley, and Truett V. DeGeare. 1975. Use of the water balance method for predicting leachate generation from solid waste disposal sites. EPA/530/SW-168.

20. Gage, S.J. 1979. "The Role of Research and Development in the Environmental Protection Agency's Approach to the Toxic Pollutants Problem," Measurement of Organic Pollutants in Water and Wastewater, C.E. Van Hall, ed., American Society for Testing and Materials, STP 686. Philadelphia. 3 pages.

21. Glaze, W.H. and Peyton, G.R. 1977. "Total organic halogen as water quality parameter: adsorption/microcoulometric method." Environmental Science and Technology, Volume 11, No. 7, pages 685-690.

22. Howard, Abby. 1978. Personal injury, economic damage, of fatalities from hazardous wastes. Unpublished list of reports, catalogues and damage cases on file at the USEPA.

23. Illinois Environmental Protection Agency. 1977. Special-Waste Land Disposal Permits Criteria.

24. Illinois Environmental Protection Agency. 1977. Special and/or Hazardous waste permit information, Module E.

25. Jekel, Martin and Reinhard, Martin. October 1979. "Total and specific compound analysis in advanced treated wastewaters" (paper presented at the Pacific Conference on Chemistry and Spectroscopy, Pasadena, California).

26. Jekel, M.R. Undated. "The determination of total organic halogen (TOX) as practiced at the Stanford Water Quality Control Research Laboratory, Department of Civil Engineering, Stanford University, Stanford, CA 94305."

27. Joyce, Robert (Dohrmann/Envirotech). Personal telephone communication. Subject: "Users of TOX instrumentation." April 2, 1980.

28. LeGrand, Harry. 1979. Evaluation of ground-water contamination potential from waste disposal sources. EPA contract No. 68-01-4405.

29. Lohman, S.W. et al. 1972. Definitions of selected ground-water terms - revisions and conceptual refinements. USGS Water Supply Paper 1988.

30. Lohman, S.W. 1972. Ground-water hydraulics. U.S. Geological Survey Professional Paper 708.

31. Louisiana Department of Natural Resources Regulations, Sections 5.5.2 and 8.4.10. August 1979.

32. Martin, R. Jekel, and Paul Roberts. 1979. Total organic halogen measurements for the characterization of reclaimed water. Submitted to Environmental Science and Technology.

33. Maryland Natural Resources Code. March 1977 (as amended). Title 8, Section 1413.2(c), Chapter 618.

34. Maryland Water Resources Administration Regulation 08.05.05. Amended through July 1978.

35. Minnesota Regulations for Hazardous Waste Management. June 1979.

36. Mooij, H.; et al. 1977. Recommended procedures for landfill monitoring program design and implementation. Environment Canada. EPS 4-EC-77-3. 25 pages.

37. National Academy of Sciences and National Academy of Engineering, 1972. Water Quality Criteria 1972, Report prepared by Committee of Water Quality Criteria at request of U.S. Environmental Protection Agency, Washington, D.C., 594 pages.

38. New Jersey Department of Environmental Protection. 1977 (as amended). New Jersey Administrative Code 7:26-1 et seq.

39. New York Department of Environmental Conservation. August 1977. Rules and Regulations, Part 703 et seq.

40. New York Department of Environmental Conservation. August 1977. Part 360.8 et seq.

41. Ohio Environmental Protection Agency, Division of Hazardous Wastes. June 1976. Criteria for Landfill Disposal of Hazardous Wastes in Ohio.

42. Ohio Environmental Protection Agency. June 1976. Draft criteria for the disposal of very hazardous wastes in Ohio.

43. Ohio Environmental Protection Agency. Investigations by Ohio EPA ground water group - specific contamination cases. Hamilton County.

44. Ohio Environmental Protection Agency. Investigations by Ohio Environmental Protection Agency ground water group - specific contamination cases. Monroe County. Unpublished list.

45. Oliver, B.G. 1979. Chlorinated nonvolatile organics produced by reaction of chloride with humic material. Canadian Research, 11 (6):21-22.

46. Oxidation Techniques in Drinking Water Treatment. 1978. In: Proceedings of Karlsruhe Conference, F.R.G., held Sept. 11-13. H. Sontheimer, ed., EPA-570/9-79-020, 39 pages.

47. Pennsylvania Department of Environmental Resources. 1975. Water quality management and solid waste management. Supplementary Geology and Ground Water Information, Module 5A - Phase 1.

48. Pennsylvania Department of Environmental Resources. June 1977. Pennsylvania Administrative Code, Section 75.38 et seq.

49. Pesticides and Pesticide Containers, Regulations for Acceptance and Recommended Procedures for Disposal and Storage, FR 39 (86), May 1, 1974.

50. Piskin, R. July 1976. Suitability of landfills for disposal of hazardous wastes in Illinois. Waste Age.

51. Polychlorinated biphenyls; criteria modification, hearings FR 44 (106), May 31, 1979.

52. Public Health Service. 1962. Drinking Water Standards, U.S. Department of Health, Education and Welfare, Washington, D.C., 61 pp.

53. Shuster, K.A. 1976. Leachate damage assessment - case study of the Sayville solid waste disposal site in Islip (Long Island), New York. EPA/530/SW-509. 18 pages.

54. Shuster, K.A. 1976. Leachate damage assessment - case study of the Fox Valley solid waste disposal site in Aurora, Illinois. EPA/530/SW-514. 34 pages.

55. Silka, Lyle R. and Ted L. Swearingen. 1978. A manual for evaluating contamination potential of surface impoundments. EPA 570/9-78-003.

56. South Carolina Proposed Hazardous Waste Management Regulations, Sections R61-79.4.

57. Standard Methods for the Examination of Water and Wastewater. 1976. APHA, AWWA, WPCF, 14th ed. Washington, D.C.

58. Texas Department of Water Resources. January 1979. Technical Guideline No. 6 (draft revision) - Monitoring Systems and Leachate Collection.

59. Texas Water Quality Board. May 1976. Technical Guideline No. 6, Monitoring/Leachate Collection Systems.

60. Texas Water Quality Board. 1977 (as amended). Industrial solid waste management regulation, Section 3-07.

61. U.S. Environmental Protection Agency. 1973. The effective use of high water table areas for sanitary landfill. EPA-SW75d.1.

62. U.S. Environmental Protection Agency. 1973. Handbook for Monitoring Industrial Wastewater, Technology Transfer.

63. U.S. Environmental Protection Agency. 1973. Manual of Individual Water Supply Systems, Office of Water Programs. 164 pages.

64. U.S. Environmental Protection Agency. March 1979. Methods for Chemical Analysis of Water and Wastes. EPA-600/4-79-020.

65. U.S. Environmental Protection Agency. National Interim Primary Drinking Water Regulations, 40 CFR 141.

66. U.S. Environmental Protection Agency. 1977. The prevalence of subsurface migration of hazardous chemical substances at selected industrial waste land disposal sites. EPA/530/SW-634.

67. U.S. Environmental Protection Agency. 1974. Report to congress: disposal of hazardous wastes. EPA SW-115.

68. U.S. Environmental Protection Agency. January 1977. Report to congress - waste disposal practices and their effects on ground water. 531 pages.

69. Walpole, Ronald E. and Raymond H. Myers. 1972. Probability and statistics for engineers and scientists. Macmillan Co., New York. Pages 187-192, 242-245.

70. Washington State Administrative Code - Hazardous Waste Regulations, Chapter 173. 302.280. January 1978.

71. Wegman, R.C. and Greve, P.A. 1977. "The microcoulometric determination of extractable organic halogen in surface water; application to surface waters of the Netherlands." The Science of the Total Environment, Volume 7, pages 235-245.

72. Weston, Roy F., Inc. 1979. Pollution prediction techniques for waste disposal siting - a state-of-the-art assessment. U.S. Environmental Protection Agency Report SW-162c.

73. Wilson, L.G. August 1979. Monitoring in the vadose zone: a review of technical elements and methods. Unpublished Report, EPA Contract No. V-0591-NALX.

74. Wisconsin Department of Natural Resources. 1977. Hazardous waste management guidelines and procedures.

75. Wisconsin. 1977. Assembly Bill 880, Section 17 (144441).

76. Wisconsin Department of Natural Resources. 1974. News release copy on file at EPA.

Attachment No. 1

Damage Cases

The following is a detailed description of the documented damage cases illustrating the potential for groundwater contamination from hazardous waste land disposal sites:[22]

1. The Ansul Company manufactures agricultural herbicides in Marinette, Wisconsin, which resulted in the production of salt wastes containing arsenic. The company had accumulated many tons of these salts at their plant location. Surveys by Ansul and the Wisconsin Department of Natural Resources (DNR) had indicated localized heavy groundwater contamination. Contamination of the Menominie River, adjacent to the plant, had occurred with maximum levels in the sediment found to be 35 ppm of arsenic (USPHS standard is 0.05 ppm). The river contamination had been attributed to 7,500 tons of the salt wastes which has been stored on a loading dock within 10 feet of the river. A well at the dock had been found to yield water containing about 1.0 mg/l arsenic. The DNR had ordered the Ansul Company to construct new storage facilities for the salt wastes. Two new storage facilities were to be built, the first for the daily salt waste production and the second for the wastes currently stored on site.

2. An aluminum plant in Monroe County, Ohio had grossly contaminated the ground water under its site with flourides, high pH, and other trace chemicals. The water was also discolored. The source of contamination was leachate from a used tailing pond and used potline piles. As a partial solution the firm was treating the pollution source with acid. They have also developed interceptor wells between their source of pollution and their main production well. The OEPA did recognize that these actions were beneficial in containing the pollution within the aquifer under the firms site. However, if the firm were to discontinue operations and thus discontinue the use of the main production well, the use of the inceptor well, and the use of acid treatment the site would be a major source of pollution for many years after the plant closed.

3. A chemical plant in Hamilton County, Ohio which utilizes two infiltration lagoons for waste disposal had contaminated a very productive aquifer. This was discovered recently when a new well was developed on a nearby property. Follow up studies revealed that several other wells in the area were also contaminated. Abnormally high values of sodium, potassium, nitrogen, sulfates, phenols and high TOC values were found. A few of these constituents in several of the contaminated wells exceeded standards for drinking water.

4. An arsenic pesticide was used to control a grasshopper infestation near Perham, Minnesota in 1934. After the infestation was under control, the unused pesticide was buried in an unmarked shallow trench far from any urbanized areas. In 1972 a shallow well was installed near the pesticide disposal area to serve as a water supply for a local construction company. Soon after the well was placed in service, thirteen employees were stricken with what was later diagnosed to be arsenic poisoning. All of the thirteen employees required medical treatment and two had to be hospitalized. One employee was hospitalized for more than a month and still suffers from nerve damage.

5. Since August 1968, a commercial laboratory in Myerstown, Pennsylvania, has disposed of its arsenic waste by surface storage within the plant area (some of waste materials not known). This practice apparently has led to contamination of the ground and subsequent migrations into groundwaters through leaching, ionic migration actions, etc., abetted by the geologic and edaphic character of the plant site. In order to meet discharge requirements and/or eliminate the waste hazard, the company has had to design and construct a system of recovery wells to collect the arsenic effluent from groundwaters in the area. Recovered arsenic and current arsenic waste (previously stored on the land) are now retained in storage lagoons. Presumably, the sludge from these lagoons was periodically reclaimed in some way. Lagoons of this type are generally not well attended and may result in environmental catastrophes.

Attachment No. 2

State Laws and Regulations

A survey of various state hazardous waste regulatory programs yielded the following information:

California

The California State Water Resources Control Board is the agency regulating disposal sites and monitoring of hazardous wastes. Monitoring plans are developed case-by-case, based upon the detailed geologic and hydrologic requirements of the permit.[10] The monitoring programs for hazardous waste disposal facilities may include any or all of the following components:

1. Monitoring of local ground and surface water from locations considered to be within the radius of influence of a disposal site; and from a background location. These data may be compared. The regulations observe that collection of baseline data is important because it may offer a basis to discount claims of degradation of water quality which may be filed later by other parties.

2. Periodic site inspection, sampling, and analysis of wastes performed by agency personnel. The operator is allowed to collect samples for replicate analysis.

3. Installation of piezometers or monitoring wells at critical locations.

4. Operation of continuous fluid level measuring instruments at seepage collection drains and dumps.

5. Monitoring wells, located on the basis of local ground and surface-water hydrology, from which the disposer may be required to collect samples.

The selection of constituents for analysis and evaluation is related to the type of waste being disposed. The basic program includes testing for pH, electrical conductivity or total dissolved solids, chloride, hardness, and total alkalinity. Specialized monitoring of hazardous waste disposal may require sample analyses for toxic materials, heavy metals, organics, color, BOD, tannins and lignins, with field tests for carbon dioxide.

At sites receiving up to 200 tons of wastes daily, monitoring reports are generally required on a quarterly basis. Sites receiving more than 200 tons daily must submit monthly reports.

Illinois

The Division of Land and Noise in the Illinois Environmental Protection Agency (IEPA) is responsible for the State's hazardous waste management program. Criteria developed for land disposal of hazardous wastes place considerable emphasis upon the origin and composition of the materials to be disposed of.[23] The waste generator is required to list the standard industrial classification (S.I.C.) number for the industrial activity from which waste is derived. IEPA has assigned a number to each of the subgroups in the S.I.C. table. These numbers are used to determine the minimal scope of chemical analyses required with the permit application; this waste characterization provides a guide for future ground-water monitoring.

IEPA uses a landfill simulation leaching test to determine the environmental impact of the waste material.[24] This test is applied to hazardous wastes for which a disposal permit is required, according to the previously mentioned grouping of wastes by S.I.C. numbers. Theoretically, waste characterization should permit design of a waste constituent-oriented monitoring program at each site.

The agency usually requires installation of at least one monitoring well hydraulically upgradient and one down-gradient, placed as close as possible to the deposition area. The monitoring wells may penetrate shallow perched water zones which are widespread in Illinois. If contamination is detected, IEPA interprets this as an "early warning signal" indicating possible later contamination of the underlying water-table aquifer.[50]

Louisiana

The Department of Natural Resource's hazardous waste management regulations include provisions for surveillance and monitoring of facilities, requiring a systematic program to conduct investigations and recording of ground-water monitoring systems.[31] Specific requirements of the ground-water monitoring system address well number and location; sampling frequency and parameters; evaluation of and response to analytical results; and recordkeeping and reporting.

Maryland

The program to monitor storage and disposal of hazardous wastes in Maryland is in the early stages of implementation, following the 1976 enactment of a law entitled "Safe Disposal of Designated Hazardous Substances," and promulgation of applicable regulations by the

Maryland Department of Natural Resources (DNR). The law requires that the DNR "establish procedures for monitoring of hazardous and industrial substances from the time of generation to the time of final disposal."[33] It specifically directs the DNR to set minimum requirements for ground-water monitoring.

The DNR's regulations require detailed hydrogeological information (e.g. soils, rock formations, boring results) to be submitted by the permit applicant.[34] The applicant must also present information on the ground-water monitoring system design, including background ground-water analyses and sampling procedures.

Minnesota

Hazardous waste management regulations were promulgated in 1979 by the Minnesota Pollution Control Agency.[35] These regulations require the owner/operator of a hazardous waste disposal facility, before accepting hazardous waste, to construct a monitoring system. This system would be used to determine effects in soil, ground water and air attributable to the disposal facility operations. In addition, for closure of a hazardous waste land disposal facility, ground water and surface water monitoring systems must be constructed if not already installed. The monitoring system must also be employed in the long-term maintenance of a facility after closure.

New Jersey

Regulations promulgated by the New Jersey Department of Environmental Protection (DEP) in 1975 (as amended in 1977) prohibit opening of a new solid waste facility without prior installation of a ground-water monitoring system.[38] Background water-quality data must also be obtained and recorded before any waste is deposited at the site. The DEP may also require installation of monitoring systems at the sites in operation prior to September 1975. All monitoring system approvals are made on a case-by-case basis. Each disposal facility receiving hazardous wastes must have interception, collection, and treatment systems for any leachate generated at the site.

The submission of the required monitoring data must be made annually, at which time the registrant is required to provide a statement updating the information contained in the initial registration statement. The registrant must notify the DEP within 30 days of any change in status of the operation covered by the original statement. The regulations require an extensive list of parameters to be included in the annual analyses of samples collected as part of the monitoring program.

New York

At the present time, New York State is in the process of implementing a program designed to upgrade hazardous waste disposal and monitoring practices. The program will be managed by the Hazardous Waste Bureau of the Department of Environmental Conservation (DEC).

Regulations classifying ground water and establishing water-quality effluent standards have been proposed by the DEC. The standards, if approved, will be applicable to industrial waste treatment, including hazardous waste management facilities designed both for treatment and storage.[39]

Effective solid waste management regulations set specific requirements for ground-water protection and monitoring with special precautionary measures required at land burial facilities used for hazardous waste disposal.[40] At these sites, monitoring programs will be established by the DEC on a case-by-case basis. A minimum of three monitoring wells, with two located hydraulically downgradient from the solid waste fill area, is required. Ground-water sampling frequency is set as part of the operating permit. Baseline water quality must be established prior to use of the site. The regulations are applicable to both new and modified secure land burial facilities, which are defined as "a disposal facility meeting the design and operation requirements (.....) for the proper disposal of hazardous wastes so that such wastes are immobilized or otherwise prevented from release to the environment or rendered harmless or decomposed into harmless materials within the facility."

Ohio

In 1976, the Ohio EPA promulgated new solid waste regulations which gave the Agency's Office of Land Pollution Control (OLPC), Division of Hazardous Wastes, more authority.[41] These regulations influence future monitoring of hazardous waste storage and disposal facilities two ways. They provide a specific definition for ground-water pollution, and stipulate that sites must be located in geologic formations where permeability of the clay is such that the time required for the movement of leachate through the walls or bottom of the landfill to ground water or surface water must be 1,000 years under a "hydraulic gradient of 1.2."[42] Pollution of ground water is defined as the "entrance of any substance into such waters in such quantities as to prevent or materially interfere, either immediately or cumulatively, with any use of such waters otherwise possible, or in such quantities as would require such waters to be treated prior to use." This policy of long-term protection of existing ground-water quality is further reinforced by the site data and monitoring requirements of the regulations.

The permitting procedure requires submission of a complete geologic and hydrologic report on existing conditions, including the "ground-water development potential" of the aquifer(s) beneath the disposal site. Chemical analyses of ground-water samples for 17 constituents must be submitted, with the agency entitled to request a sampling program involving "analysis of such a number of samples from such a number of wells as deemed necessary." The applicant must also provide data on the "location, surface elevation, depths, construction details, materials penetrated, water levels, available reports on future plans for, chemical sampling, and other relevant characteristics of all monitor wells to be used for ground-water sampling, and detection of leachate production and migration."

Provision is to be made for the collection, containment, treatment or disposal of leachate. The permittee is responsible for the maintenance of monitoring wells for sampling until three years after the landfill is completed.

Pennsylvania

The Division of Solid Waste Management in Pennsylvania's Department of Environmental Resources (DER) is responsible for the permitting and surveillance of monitoring programs associated with the disposal of hazardous waste throughout the State. At present, there are no facilities designed specifically for this purpose. However, since passage of RCRA, the Division has received inquiries from waste disposal firms interested in establishing facilities.

The Division's monitoring authority was strengthened considerably by a 1977 revision of State Solid Waste Management Rules and Regulations applicable to industrial waste disposal sites. The permitting procedures are designed to promote full disclosure of site and waste characteristics through a two-phase permitting procedure. Data solicited from the applicant include complete coverage of pertinent geologic and ground-water conditions.[47] Phase I requires the applicant to describe monitoring proposed as part of the project, and to delineate specific monitoring points. However, the permit application advises that "wells are not to be drilled until the Department approves the design, location, and specifications." The regulations stipulate that "monitoring points should not be located more than 500 feet from the permitted area, in order to obtain ground-water samples capable of being analyzed for contaminants as close as possible to the actual place of deposition."[48]

One monitoring well must be installed hydraulically downgradient and one monitoring well upgradient from the deposition area. This is considered to be the minimum requirement for each project. However, DER approval of hazardous waste monitoring projects is to be on a

case-by-case basis with provision for additional monitoring wells at the discretion of the agency. Design of the monitoring wells and sampling procedure are dictated by the terms of the project permit.

The regulations stipulate that each monitoring well must be purged prior to obtaining water samples. Chemical analyses of water samples from the monitoring well and other hydrologic data must be submitted quarterly. Constituents included in the analyses are determined on a case-by-case basis, according to the chemical and physical properties and the volume of the materials disposal of.

South Carolina[56]

South Carolina's proposed regulations for hazardous waste management facilities include requirements for ground-water monitoring, addressing well number and location; sampling frequency and parameters; evaluation of and response to analytical results; and record-keeping and reporting.

Texas

The Texas Water Quality Board (Board) is actively involved in a program to insure that ground-water monitoring requirements are satisfactory at both on-site and off-site hazardous waste management facilities. Owner/operators are required to install ground-water monitoring systems meeting the specifications of the Board's May 1976 guidelines (draft revision, January 1979) or institute other equivalent procedures acceptable to the Board.[58,59] Long-term post-operational surveillance is required in order to minimize possible damage to ground or surface water beyond the site.[60]

The guidelines establish a three-phase monitoring program. Phase I involves sampling to establish background water quality at the site. Phase II consists of a periodic sampling of monitoring points, the initial results of which must be reported to the Board monthly during the first year of site operation, and quarterly thereafter. Phase III of the monitoring program extends sampling and analysis of ground water for a period of time after the site is closed. The sampling frequency and time period of monitoring after closure is established by the agency at the time of permitting. Registration of hazardous waste disposal operations is on a case-by-case basis with the number of monitoring points set by the agency. The registration procedure was initiated as a means of obtaining information on existing waste disposal sites.

Sampling point distribution and monitoring procedures are determined by hydrogeologic conditions and types of waste likely to be encountered. The proposed revised guidelines developed by the Board

recommend a minimum of four monitoring wells under ideal conditions, that is, where the underlying earth materials are fairly homogeneous, relatively permeable, and uniformly sloping in one direction. The monitoring wells should be located upgradient and downgradient of the waste management activity with respect to ground-water flow. In cases of multiple aquifer systems, each water-bearing formation should be monitored.

All monitoring wells should be cased, with the annular space between the zone of saturation and the surface completely backfilled or plugged with cement or packed with clay, to prevent percolation of surface water into the well bore. The well casing must be fitted with a removable cap to prevent entrance of runoff and rainfall.

If contamination is noted by the owner/operator, a report must be submitted to the Board, as well as a plan to determine the contamination source. If the facility is the source, a corrective action plan must be submitted to the Board.

Washington

Washington's hazardous waste regulations require monitoring wells under each "burial trench" and "evaporation pond" to be checked at least quarterly.[70]

Wisconsin

The Wisconsin Department of Natural Resources (DNR) views monitoring as one portion of the total hazardous waste management program, required principally as a surveillance tool with the data generated to be used in enforcement procedures.

Under a proposed law, facilities approved by DNR would not be required to obtain any local permits or authorizations which may otherwise be necessary to operate the facility.[75] Licensing would involve three steps, with monitoring and closure plans to be submitted as part of the first step for the feasibility report. A waste classification plan incorporated in the law would assign all waste to classes, based upon the relative degree of hazard posed by the waste. The principal emphasis on monitoring devices is related to the long-term care provisions of the proposed law. In the original plan of operation, the DNR can require up to 10 years of long-term care, unless the licensee agrees to a longer period of time. After this time period expires, a decision on termination is to be made by the DNR.